Royal Commission
on Canada's Economic Prospects

Mining and Mineral Processing in Canada

by John Davis

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This Commission, I know, would also like to express its appreciation for the considerable interest and assistance which it has received from the Federal Department of Mines and Technical Surveys. Various of its officers have supplied supporting memoranda on request and later assisted in the final editing of this report. The help received from Mr. W. K. Buck and Mr. M. F. Goudge and their staff warrants special mention. Further acknowledgement of their services and those of other officers in the Mines Department appear in the bibliographies appended to the various sections and chapters which follow.

John Davis

Ottawa,
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SUMMARY

THE MINING industry, together with its related processing activities, is expected to become an even more influential sector in the Canadian economy. Expanding to between three and four times its present size between now and 1980, it may maintain its lead over the mineral fuels, coal, oil and natural gas, and pass the forest industries during the quarter century under review.

Because of this, and because of the high proportion of Canadian mine output which will continue to enter into international trade, metals, industrial minerals and structural materials together may account for as much as one-third of the nation's commodity exports 25 years hence. The corresponding figure was 9% in 1929 and 25% in 1955. Though offset to some extent by mounting expenditures on foreign-produced machinery and equipment and by increased payments of interest and dividends abroad, future developments in the Canadian industry will also have a favourable effect upon the nation's balance of payments during the forecast period under review.

These prospects, to be better understood, must be viewed in their world perspective. Everywhere, the demand for building materials, machinery and equipment and consumer durables is rising. Meanwhile, reserves in some of the older and still productive mining areas are approaching exhaustion; other sources, though still capable of expanding their output, are failing to keep pace with the fresh demands continually being placed upon them. Thus Canada, because of its tremendous physical extent, favourable geological conditions and stable political environment, will become an even more important supplier of minerals. This will be true particularly of sales in the United States. There, geographical proximity and rising costs of production both favour greater dependence upon this country as a source of raw and partially processed materials.

Meanwhile, Canada's mineral economy will be both broadened and deepened. No longer will this country's role be confined to supplying a few traditional products like gold, copper, lead, zinc and nickel. Large tonnage commodities like iron ore and potash are now in considerable demand. Besides uranium, titanium and such little known elements as lithium and columbium, production of industrial minerals like gypsum, salt, barites and fluorspar is also on the increase. As a result, Canada's trading pattern in minerals is changing both in character and as to country of destination.

While the volume of Canadian mineral output will continue to rise, prices are not generally expected to follow suit. On the contrary, those of the majority of Canadian produced minerals may show a moderate decline relative to that of other goods and services. With a few exceptions, such as asbestos, the historic trend in real price terms has been downward. New techniques, improvements in mine and plant layout and equipment, and advances in technology at all levels from exploration and development through to mineral processing and marketing, have continued to effect economies which, in the main, have offset such increases as have been characteristic of the older and more seriously depleted mining areas. On balance, it is assumed that these cost-reducing influences will have a similar, though at times delayed, effect upon the course of mineral prices throughout the 1960's and 1970's.

A close examination of past data suggests the real price of such metals as aluminum, magnesium, lead, zinc and titanium, may continue to move downward over the next quarter century. Some may drop by 10% or 20%; others, which are only now beginning to be used in considerable volume, may witness cost and price reductions in the order of 50% or more. Much the same conditions will apply in respect to the majority of Canadian-produced industrial minerals and structural materials. Meanwhile, the price of iron ore, gypsum and, possibly, sulphur may remain comparatively unchanged relative to that of all other goods sold on a large volume basis. Only in respect to copper among the metals and asbestos among the industrial minerals has a continuing upward movement in real price been envisaged.

The Canadian economy may be expected to gain as a result of the further processing prior to export or re-export of Canadian produced and imported minerals. The availability of natural gas in, or close to, a number of the nation's larger mining areas will be an important factor. Even more persuasive influences working in this direction will be the growth of the domestic market for minerals required in semi-processed form by the nation's vehicle, machinery and equipment and other capital goods industries.

Yet serious limitations may also be encountered. There is an upper limit to the amount of low-cost power which can be obtained from advantageously situated hydro sites in Canada. Regionally, Canadian gas may be available at lower prices in the United States. This, together with such advances as could be made elsewhere in the production of electricity by nuclear means, could cause a levelling-off in Canadian exports of such high energy content commodities as aluminum, titanium and uranium-235. Meanwhile, tariff barriers will continue to prevent such new metals as titanium and most industrial minerals from entering the United States in any but the most lightly manufactured of forms. The threat of quotas may, by increasing the risk of heavy outside investments, postpone the refining in this country of more lead and zinc. This, plus the stimulus to process plant construction provided by

stockpiling contracts, rapid write-offs and similar defence considerations will continue to encourage the further treatment of resources in countries other than Canada.

Other forces of a more fundamental economic nature will also be at work. The pull of the market, already substantial, may be augmented by the need for a ready outlet for by-products. Technical and market liaison is often facilitated. Open capacity as a result of local resource depletion is often sufficient to initiate this trade. Construction and machinery and equipment costs may well be lower or demand fewer dollars when the manufacturing is done elsewhere. For these and other reasons the perceptible downdrift in the processing of Canadian resources which have been characteristic of the last 15 to 20 years is expected to continue.

As between broad categories of minerals, demand is showing little change with respect to some; mounting rapidly in the case of others. Over the long run, consumption of such non-metallic minerals as salt, asbestos, potash, and phosphate rock has been growing at a rate in excess of 5%. Structural materials, including building stone and cement requirements, have been moving upward at a 4% rate. The utilization of iron and the ferro-alloying elements, meanwhile, has been lagging behind. Their long-term upward trend has been in the order of 2.5%. For all other metals, 3% to 3.5% has been the general rule.

Since the majority of these movements are expected to persist over the next 20 to 30 years, the metals are expected to lose some ground relatively to the non-metals. Industrial minerals may grow relatively in importance. Not only are they and the structural materials increasingly replacing wood but they are also urgently required by the fast-growing industrial chemical and related chemical process industries. The demand for new metal production, meanwhile, will be subject to such moderating influences as re-use in the form of scrap and competition from a number of the more abundant non-metals in a variety of structural applications.

Even wider variations exist in respect to individual metals and non-metals. Growth rates well in excess of 10% are currently being experienced in respect to a number of the more recently developed elements like titanium and magnesium. The demand for aluminum is still in excess of 9% per annum. Long-run average consumption increases in respect to other minerals which are also of firsthand interest to Canada are: nickel, 5%; asbestos, 5%; potash, 4.5%; gypsum, 4%; copper, 3%; zinc, 2.5%; iron ore, 2% and lead, 1.5%.

That this country possesses the necessary resources to sustain much higher levels of output, there can be little doubt. Proven reserves are adequate to support present levels of production in most mines for 20 or 30 years. More ore in the same or adjoining deposits will doubtless be proven up as their programmes are accelerated. Also, a number of new mines will be

brought in. The fact that less than one-third of the nation's favourable land area has so far been covered by geological reconnaissance mapping, itself indicates the immense potentialities for future mineral production in Canada.

Given expanding markets, Canada's role both as a producer and world trader in minerals will be enhanced. The nation's output of aluminum ingot, based on low-cost water-power and imported ore, might rise to the point where it exceeded in value that of the first two Canadian-produced minerals combined. Iron ore production, by 1980, may exceed $600 million annually. Depending upon price and the extent to which Canadian source material is processed in this country, the value of output of nickel, copper and uranium may range upward to $400 million. Others among the non-ferrous metals whose value of output in 1980 could be up to twice its present level include lead and zinc. Magnesium and titanium, along with production for the first time of such elements as manganese and lithium, may also make a sizable contribution to the nation's output of primary products. Gold is an exception. Without an increase in the present price, it is expected that production of this metal will continue to decline.

Among the industrial minerals, potash is likely to make the greatest gains. Both production and exports in this case may soon be measured in tens of millions of tons. Sulphur, recovered as a by-product of metal mining and from natural gas, will be used increasingly in lieu of the Frasch mined product. As for gypsum, Canada, besides meeting most of its own needs, will continue to be a major supplier to building products manufacturers in the northeastern United States. Exports of barites and fluorspar will increase substantially. Asbestos, meanwhile, will continue to be far and away the largest dollar value item produced by mines of this category in Canada.

A word should be said about structural materials. Geared essentially to local requirements, output may multiply between two and one-half to three times over the next quarter century. Headed by cement and brick they will continue to displace wood and supplement the metals and industrial minerals like gypsum in most types of construction. These trend expectations are reflected in highly generalized fashion in Table 1.

Table 1

ESTIMATED VALUE OF PRODUCTION OF MINERALS AND PRIMARY MINERAL PRODUCTS

(value in millions of constant 1955 dollars)

Year	Metals[a]	Industrial minerals[b]	Structural materials	Total
1955	1,235	187	228	1,650
1980	4,200	750	550	5,500

a Excluding primary iron and steel.
b Including artificial abrasives.

Canada has never been self-sufficient with respect to primary mineral products. As recently as 1955, imports accounted for approximately one-quarter of the nation's internal requirements. Purchases abroad involved an expenditure of foreign exchange in the vicinity of $220 million in that year. Because Canadian industry may be engaged even more intensively in the processing of foreign-produced minerals, this country's dependence upon external sources of supply may be increased from something like 25% as at present to approximately one-third of all Canadian requirements in 1980. Exports, by then, may exceed imports by a ratio of better than three to one. Sales abroad of iron ore, other metal concentrates and products and industrial minerals principally in their unmanufactured form might, by then, exceed $2.4 billion. Mineral imports, meanwhile, might rise from $220 million to around $750 million in 1980.

A complete accounting of Canada's balance of payments with respect to minerals also involves allowances for purchases elsewhere of machinery and equipment and payments to non-residents in the form of interest and dividends on foreign capital invested in this country. With the Canadian content of the mining industry's investment programme increasing and Canadian investor participation possibly becoming more important, it is likely that the $1.7 billion surplus on mineral commodity account will be sufficient to offset a rising in these accompanying demands for foreign exchange and, at the same time, yield a net return of better than $1 billion annually 25 years from now.

Employment in the nation's mining and mineral processing industries is forecast as rising from 110,000 in 1955 to more than 200,000 in 1980. Relative to the nation's total employed labour force, this also means the mining sector will continue to provide work for just over 2% of the nation's total labour force.

One of the more comprehensive, and possibly the most descriptive, measures of expansion is value of output. Including production for export, it is already double expenditures on consumption. The combined value of output of the various mining and mineral processing industries in Canada was equivalent to about 5% of the nation's total production of goods and services in 1955. An aggregation of the accompanying forecasts indicates that their gross value of production may be in the vicinity of $5.5 billion or between 6% and 7% of the nation's Gross National Product (G.N.P.) in 1980. Currently (1955) it is in the order of $1.6 billion.

With the exception of gold, no serious supply problems are likely to be encountered. Yet because:

(i) the mining sector will continue to grow much more rapidly than the rest of the economy;

(ii) it will continue to be dominated by large internationally controlled corporations;

(iii) the rising proportion of Canada's export trade in minerals will be conducted between Canadian-based subsidiary and parent companies elsewhere; and

(iv) because of the technical aid, special tax, transportation subsidy, and other concessions which the mining industry has been able to obtain from the Canadian federal and provincial authorities;

this many-sided area of industrial development is likely to be of increasing interest to the Canadian public as the years go by.

Table 2

ESTIMATED EMPLOYMENT IN CANADA'S MINING AND MINERAL PROCESSING INDUSTRIES, 1955 AND 1980

(employment in thousands of persons)

Year	Mining	Mineral processing[a]	All mining industries	National total	All industry in Canada[b]
				per cent	
1955......	74	36	110	2.1	7.9
1980......	130	75	205	2.1	8.0

a Excluding primary iron and steel.
b Mining and manufacturing only.

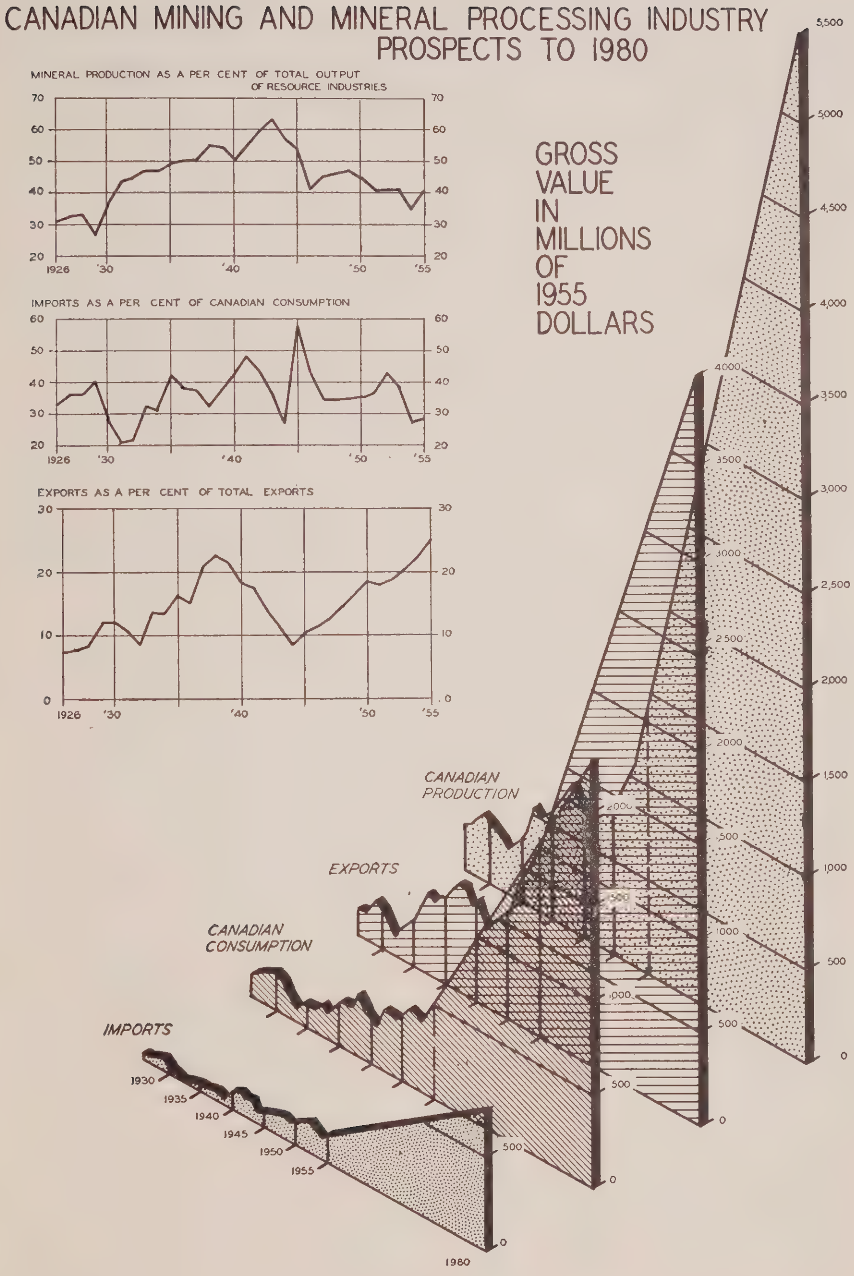
Table 3

ESTIMATED VALUE OF INTERNATIONAL TRADE IN ORES, CONCENTRATES AND PRIMARY MANUFACTURED MINERAL PRODUCTS

(value in millions of 1955 dollars)

Year	Imports[a]		Exports[b]	
	$ millions	% of total	$ millions	% of total
1955............	220	5	1,079	25
1980............	750	5	4,000	35

a Valued at point of entry. Includes diamonds, building stone, emery, artificial abrasive grains, fullers earth, etc.
b Valued at source; *i.e.*, excludes value added by transportation in Canada.
a, b Refer to commodity trade only.



CANADIAN MINING AND MINERAL PROCESSING INDUSTRY
PROSPECTS TO 1980
MINERAL PRODUCTION AS A PER CENT OF TOTAL OUTPUT OF RESOURCE INDUSTRIES
IMPORTS AS A PER CENT OF CANADIAN CONSUMPTION
EXPORTS AS A PER CENT OF TOTAL EXPORTS
GROSS VALUE IN MILLIONS OF 1955 DOLLARS
CANADIAN PRODUCTION
EXPORTS
CANADIAN CONSUMPTION
IMPORTS
1930
1935
1940
1945
1950
1955
1980

1

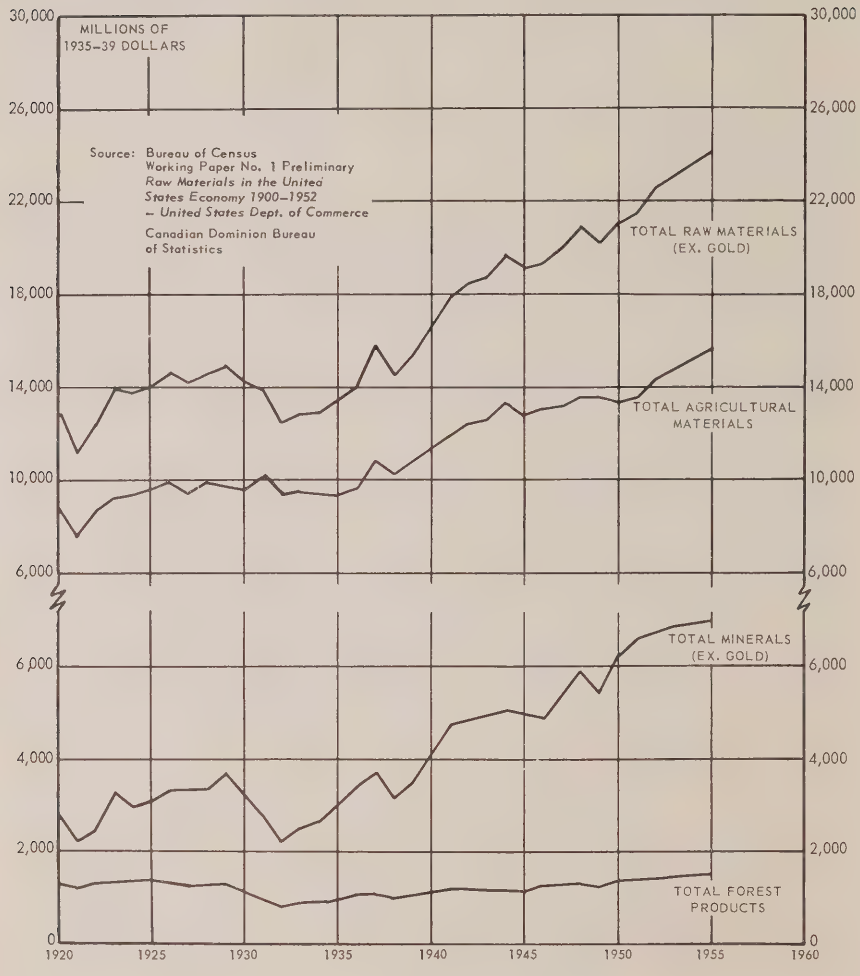
INTRODUCTION

An adequate supply of minerals is essential to industrial progress. Their use underlies, and indeed has made possible, the great mechanical, electrical and chemical revolutions which have characterized the last 200 years of man's existence. Employed in growing numbers and in a host of forms, many of which were either unknown or regarded as laboratory curiosities a quarter of a century ago, their production now constitutes one of the most rapidly expanding sectors of the Canadian economy.

Metals, in particular, have entered the spotlight. Commercial requirements, accentuated by defence considerations, have encouraged the search for fresh resources and made possible the mining of known ore bodies on a scale previously unsurpassed in the history of mankind. Meanwhile the industrial minerals—and these include such commodities as asbestos, gypsum and potash—have been forging ahead at an even greater rate. Each year since the end of World War II the majority of these non-metals have experienced rates of increase in consumption at least twice those reported for such common metals as copper and iron.

Compared to the industrial minerals, the products of agriculture and the forest have been relative laggards. On this continent, for example, the total volume of wood products presently entering consumption is only moderately above that reported in the mid-1920's. Agricultural material (chiefly food) requirements have risen by about two-thirds. The use of metals, meanwhile, has approximately doubled; that of the non-metallic minerals (exclusive of the mineral fuels) has multiplied approximately threefold. Thus the long-run demand for the products of the mining and mineral processing industries with which we are chiefly concerned in this report appears to be rising at a rate well above that of raw materials in general. (See chart entitled Consumption of Raw Materials in North America, 1920-55.)

CONSUMPTION OF MAJOR RAW MATERIALS IN NORTH AMERICA, 1920 – 1955



This is no passing phase. Industrial material requirements, like population and such aggregative measures of economic growth as G.N.P., are following an upward curve similar to that of interest compounding annually in a saving bank account. Raw material inputs, while they are geared closely to the primary and less rapidly expanding areas of economic activity, are also being drawn inexorably upward by a mode of living which puts considerable emphasis upon material well-being.

Such synthetic substitutes as the plastics, while they may affect the outlook for certain minerals, are unlikely to be available at prices and in quantities sufficient to affect substantially the intimate relationship between mineral consumption and economic growth. Scrap and other reclaimed material will continue to be returned to the supply stream. However, the principal impact of these recovery practices has already been felt. Designers and architects have, for years, concerned themselves with minimizing the amount of metal and other minerals employed in industrial processes, in the manufacture of vehicles, the production of other types of machinery and equipment, and in construction generally.

Appreciable economies remain to be effected on each of these fronts. Yet, in view of the persistent manner in which demand has continued to rise over the past half century it would appear reasonable to assume that:

(i) the demand for metals will continue to grow at a rate of approximately 3% a year;

(ii) most industrial minerals may experience an annual rate of growth in the vicinity of 5% or 6%; and

(iii) the majority of structural materials (including cement, brick and stone) will continue to experience a yearly increase in consumption of between 2% and 3% over the next quarter century.

One cannot, at the same time, conclude that the growth of most mining and mineral processing industries has been (or will be) both steady and inevitable. Linked closely to the demand for hard goods, mines, smelters and refineries everywhere have been among the first to feel the effects, good or bad, of the business cycle. Their fortunes have also been determined, in no small measure, by wars and other defence measures; events which, like peacetime booms and depressions, have caused production and prices to move together, first in one direction, then another.

Fortunately this close relationship with capital investment has been lessening somewhat. The metals are being used more extensively in the manufacture of consumer durables, containers and packaging materials. The market for certain industrial minerals like potash is becoming more intimately related to food consumption. These tendencies, together with the need to maintain and repair an ever mounting stock of capital goods, has

introduced a greater element of stability into the activities of the mines and other primary mineral industries than has prevailed in the past.

These influences have been making themselves felt, but in varying degree, from one mineral to the next. Some, due to their great abundance in nature and to the development of novel processes for their extraction, have begun to be used much more extensively. This is true of aluminum, magnesium and titanium. Others, due to the fact that new capacity can be created at comparatively short notice, have not only been developing new markets but have frequently been displacing some of the older and better-known minerals from their traditional applications. Other mineral fibres in competition with asbestos and cement among the structural minerals have been particularly successful in this respect. Meanwhile the comparative stability in the real price of most metals and other minerals have enabled these industries to eject wood from a variety of uses in which it was at one time regarded as impregnable.

While there has been a good deal of give and take, the emergence in commercial quantities and at reasonable prices of new products has frequently augmented the demand for minerals as a whole. The light metals, due to their high strength-to-weight ratios, have made the airplane possible. The aircraft industry, in turn, has helped to speed up other activities of both an industrial and a commercial character. Uranium, as its physical and chemical properties become better understood, will have a similar effect upon the energy sector of the economy. Like most other minerals which in their final applications are used jointly rather than separately, it would draw an even wider range of minerals into the orbit of everyday commerce.

Impressed by the increasing volume and variety in the demand for minerals, many people have begun to question the life of existing mines. Minerals, after all, are exhaustible resources. Once mined, they cannot be replaced. The only alternatives are to look elswhere or to develop substitutes. Either course carries with it the threat of rising costs.

In recent years the spectre of resource depletion has received considerable publicity in the American press. True, some of the larger American mines are no longer able to compete in world markets. The capacity of others cannot be increased rapidly in the event of an emergency. Of necessity, more low-grade material is being treated. More waste rock is being raised for every ton of ore produced. By-product values are not always present in sufficient amounts to offset rising concentration and other processing costs. Witnessing this, defence and other authorities in the United States have come to the conclusion that they must look elsewhere for some, if not all, of the additional production which will be necessary in the event of another defence emergency.

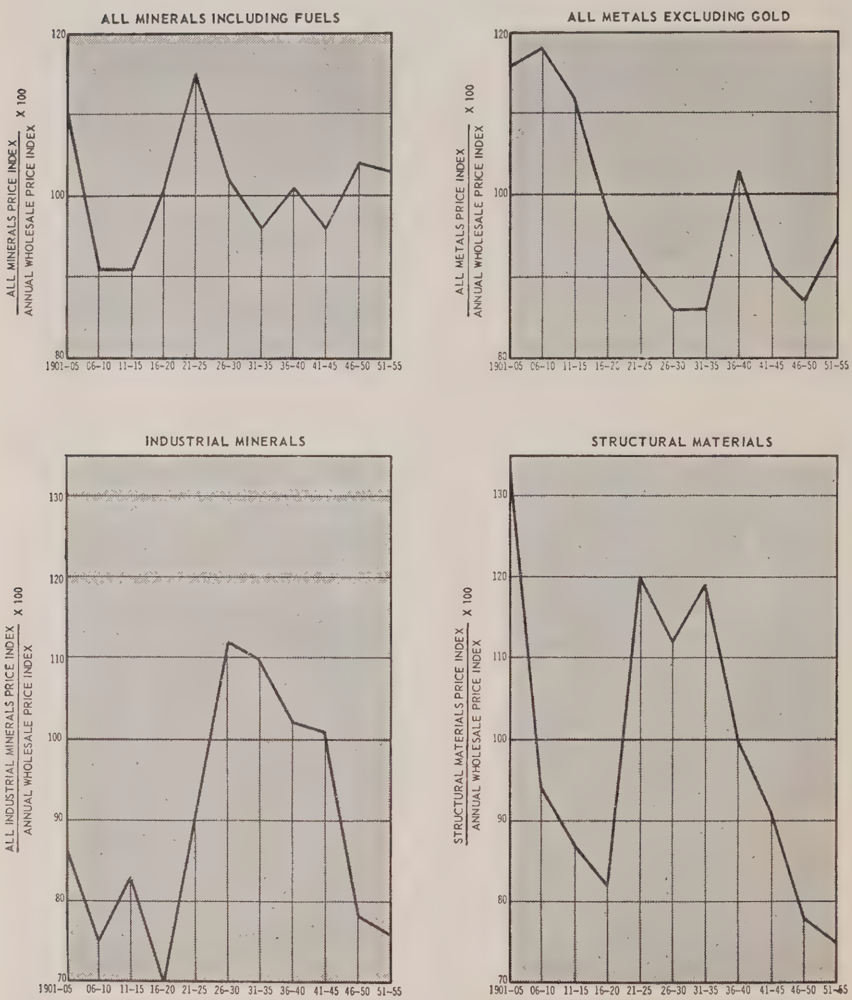
With the gradual exhaustion of many of the world's richer and more accessible ore bodies, the search for fresh resources is being pushed farther afield. At the same time, more efficient equipment and improved operating techniques are being devised. By planning and operating on a larger scale, labour and transportation costs are frequently being held in check. Beneficiation, by eliminating the greater proportion of the waste rock and other unusable material, is making possible the exploitation of ores which were frequently regarded as submarginal. Extensive on-site processing has usually added to the number of salable by-products. In the case of iron ore, it has made possible compensating economies in the steel mills. As a result of these various influences, real costs and real prices have risen much less in recent years than is generally believed to be the case.

Rising prices, where they have occurred, have often provided their own corrective. Mining and its related activities have appeared to be more profitable than before. Many mineral-using concerns with a substantial investment in processing and fabricating facilities have been inclined to secure their own sources of supply. Governments, too, have initiated projects, the main purpose of which was to provide capacities more in line with projected rather than current requirements. The outbreak of war in Korea and the prospect of a long drawn out cold war, superimposed as it has been upon a high and continuing level of commercial demand, have thus helped to set the stage for an unparalleled expansion in mining and mineral processing.

Since 1950 a great deal of effort has been expended on the reorganization of old mines and the creation of new ones. Numerous deposits, the existence of which has been known for years, have been revisited. Some, after careful probing, have turned out to be veritable bonanzas. Other deposits have come to light due to the application of novel techniques of exploration and development. This has certainly been true in Canada. Yet other countries including Cuba, Mexico, Venezuela, Chile, Peru and Brazil in Latin America; the Belgian Congo, Rhodesia and the Transvaal in Africa, have shared in this widespread and rewarding search for new mineral wealth.

The time lag between the launching of new developments and their impact on world markets can be as little as five years. More often, a decade may pass before their full effect has made itself felt. Meanwhile, as each increment of capacity begins to function, a fresh balance is struck between supply and demand. Consumption has been rising steadily, as we have seen. Yet, only in 1955 were the first ramifications of the post-Korean expansion programme beginning to make themselves felt. Prices have, in many cases, been stabilized. Those of some minerals have actually begun to decline. The number of metals and other minerals which are still in really short supply are now less than a dozen. For the first time in nearly a decade, most mineral-using industries can look forward to adequate supplies and prices which bear a close relationship to costs.

MINERAL PRICE TRENDS* NORTH AMERICA, 1901 – 1955
(FIVE YEAR AVERAGES)



* Ores and Concentrates only. The real price of primary manufactured minerals has shown a greater tendency to decline due to even greater improvements in efficiency at the smelters and refineries, etc.

In the case of a few such strategically important metals as nickel, a condition of relative scarcity may continue for a few years. Periodic shortages, as in the case of copper, may result from strikes, water shortages and other work stoppages. Yet, if we are to deny the possibility of all-out war, it would seem likely that the exceptional mine developments which are being pushed to completion in many parts of the world will serve to stabilize the price of most minerals, if not actually cause them to trend downward relative to those of other goods and services. (See charts on mineral price trends in North America, 1900-55.)

As supply becomes more plentiful, the possibility of restrictive measures again comes to the fore. The Western European countries will probably continue for some time to set import quotas for balance of payments reasons. Yet, being selective, they are not likely to impinge seriously on metals and other minerals in their primary forms. Meanwhile, the United States, because of its increasing deficit position, is less likely to resort to higher tariff and other protective devices. Only in the case of lead and zinc is there a real possibility that special measures of this type will be invoked by this, the most influential of the major importing nations.

Uncertainties of this kind will continue to militate against on-site processing, in source countries like Canada. Smelters and oil refineries are expensive to build. Hence they must be assured of being able to operate at or close to capacity throughout their useful life. Obsolescence, due to unforeseen technological advances, puts even greater emphasis upon a continuing high level of activity. Therefore, no mining concern which has reason to doubt its ability to gain continuous access to the world's principal industrial markets is anxious to undertake the construction of manufacturing facilities of this kind.

Graduated tariffs which are designed to permit the entry of certain minerals in their raw or lightly processed form, and at the same time to ensure a high level of activity in the smelters and refineries of the principal mineral using countries, have a similar effect. By-products, particularly those of a chemical nature, cannot be exported readily from source countries. Also, they are less likely to be employed at home in economies where secondary manufacturing is less highly developed or more widely dispersed than it is in, say, the northeastern United States. These influences, together with the fact that the ores of many of the newer minerals can be concentrated into readily transportable form, will therefore tend to limit the number and variety of mineral-based products which are exported from resource-rich countries such as Canada.

One should not be unduly pessimistic about the problems of marketing which lie ahead. Other and compensating influences are gaining strength. Long-term contracts with governments and with industry are much more

prevalent than they were prior to World War II. Subsidiary corporations are being formed and considerable amounts of money invested in countries like Canada, the purpose of which is to assure the user industries in the United States and Western Europe of a continuous source of supply. Integrated developments of this kind, while they are usually concerned with the extractive rather than the processing phases of mining, are bound to have a stabilizing influence on Canada's export trade in the years ahead.

Favouring a greater degree of processing is the growth of the Canadian market for minerals and the more favourable energy supply situation. Assured of a sizable outlet at home, the capital necessary to provide smelting and refining facilities is more likely to be forthcoming. This applies to by-product chemicals as well as to metals in their primary ingot and industrial minerals in manufactured form. The incentive will be even greater where the deposits in question are readily susceptible to treatment by pressure leaching or electrolytic refining. The availability over wider areas of cheap natural gas or hydro-electric energy will be of material assistance in this latter respect. So will the expansion in this country of a chemical industry capable of supplying the processing plants with chemicals at comparatively low prices.

Operations of this kind, since they would be economic in a truly international sense, could mean much to Canadians. They would help to maximize employment in and around the mines. They would provide additional opportunities for research aimed at solving essentially Canadian problems. They would provide a larger and more diversified market for the products and services of other Canadian industries. Through the growth of more complex, horizontally integrated primary industries, they can also result in a greater degree of economic stability in those areas of the country which are primarily dependent upon mining for their livelihood.

Nor is this all. An atmosphere of confidence and the greatest possible scope for diversification are, together, essential to sound conservation. Only when these conditions have been fulfilled can the nation's mining and mineral processing industries be expected to yield a return to future generations of Canadians more in line with their true value in the industrial markets of the world.

2

CANADIAN DEVELOPMENTS IN PERSPECTIVE

OVER THE past quarter century, mining has become one of Canada's principal sources of wealth. Exceeded in value only by agriculture and the forest industries, and surpassing even agriculture in respect to export earnings, Canada's mines, smelters and refineries are now turning out a volume of metals, industrial minerals and structural materials worth approximately $1.6 billion annually. Even when allowances are made for the supporting contribution of other sectors of the economy, mining and its related activities now generate approximately 4% of the nation's total output of goods and services.

Canada has come to be regarded as one of the world's major producers of non-ferrous metals. Standing first in the production of nickel, second in aluminum, gold, magnesium and zinc, third in silver, and fifth in copper and lead, the nation's mines and mineral processing plants have rightly come to be regarded as among the richest, largest and most efficient in the world. Canada has another first in asbestos. In respect to gypsum, fluorspar and barites, she is well placed. Other minerals, meanwhile, are being added to the list. Canadian-produced uranium and iron ore are fast becoming major industries in the international sense. Others, like titanium, sulphur and potash, appear to be assured of an expanding future. The outlook is therefore for a further dependence of the Canadian economy upon this technologically advanced and highly competitive area of international trade.

Mining, as a lasting industry, is a comparative newcomer to the Canadian scene. As late as the 1880's and 1890's, it was still essentially nomadic in nature. Even after 1900 the recovery of gold from streams, creeks and river bottoms in western Canada exceeded in value that of all other metals and industrial minerals produced in this country. Hard-rock mining was only in its infancy. Such markets as existed were either small or adequately supplied from better known and more accessible sources. Fifty years ago, mining and its related activities accounted for less than 1% of the Canadian G.N.P.

Table 4

CANADA HOLDS LEADING POSITION IN WORLD MINERAL OUTPUT

(based on 1955 free world production totals, in thousands)

World output rank	First	Second	Third	Fourth
Asbestos	Canada	S. Africa	S. Rhodesia	U.S.
Tons	1,064	120	105	60
Calcium metal	Canada			
Pounds	1,000	a	a	a
Nepheline syenite	Canada			
Tons	146,068	only other world producer is U.S.S.R.		
Nickel	Canada	N. Caledonia	Cuba	U.S.
Tons	175	27	15	5
Platinum metals	Canada	S. Africa	Colombia	U.S.
Troy ounces	385	364	27	not available
Aluminum	U.S.	Canada	W. Germany	France
Tons	1,566	608	152	142
Cobalt	Bel. Congo	Canada	U.S.	Fr. Morocco
Pounds	18,886	3,319	2,602	1,653
Gold	S. Africa	Canada	U.S.	Australia
Troy ounces	14,094	4,542	1,891	1,049
Magnesium	U.S.	Canada	Norway	U. Kingdom
Tons	61	9	7	6
Selenium	U.S.	Canada	Sweden	Japan
Pounds	690	427	112	72
Zinc	U.S.	Canada	Mexico	Australia
Tons	504	433	250	241
Uranium		Canada		
Tons				
Barite	U.S.	W. Germany	Canada	Yugoslavia
Tons	1,118	449	254	109
Cadmium	U.S.	Mexico	Canada	S.W. Africa
Pounds	9,754	2,855	1,919	1,402
Molybdenum ore	U.S.	Chile	Canada	
Pounds	31,150		695	
Silver	Mexico	U.S.	Canada	Peru
Troy ounces	47,956	33,101	27,984	20,955
Copper[b]	U.S.	Chile	N. Rhodesia	Canada
Tons	1,014	478	395	326
Lead[b]	U.S.	Australia	Mexico	Canada
Tons	333	309	232	203
Titanium ore[c]	U.S.	India	Norway	Canada
Tons	585	301	174	163

a Standing of other countries obscure.
b Excludes U.S.S.R.
c Ilmenite concentrates only.

REFERENCES: Canadian figures—Dominion Bureau of Statistics, final figures for 1955; all other figures—U.S. Bureau of Mines or American Bureau of Metal Statistics (1956).

The rising though irregular production curve covering the past half century tells the story in itself. Edging slowly upward at first, it received considerable impetus from the defence requirements which characterized World War I, World War II and the post-Korean emergency which began in 1950. Setbacks have also been encountered. Usually, however, they have been of relatively short duration or have affected Canadian producers less than those elsewhere. One occurred in the early 1920's; another in the mid-1940's gave the industry a short but much needed opportunity to replan its workings on a still larger scale. The most serious and downward adjustment which it had to face followed 1929 with the onset of The Great Depression. At that time output fell further and prices dropped more sharply than has been the case either before or since. Yet, the competitive strength of the Canadian industry together with the long-run worldwide upward trend in mineral consumption was such as to offset what, under other circumstances, would have amounted to an even more serious falling off in activity.

In more years than not, the industry has been confronted with a buyer's rather than with a seller's market. There were years in the early 1920's and 1930's during which a great deal of capacity was idle. Much greater tonnages could also have been produced between 1946 and 1950 had demand warranted it. Viewed against this background, the situation which has prevailed since 1950 must be regarded as exceptional. Hostilities on a global scale during World War II, followed by the additional stimulus provided by the cold war, have so taxed existing facilities as to maintain prices at a high level and to make profitable many properties which otherwise would have been unprofitable in operation.

With full employment becoming a permanent feature of modern democratic life, the considered view of future mineral requirements taken by most industrialists has become increasingly optimistic. Rather than worrying about the possibility of surpluses, they have become increasingly concerned about the adequacy of low-cost and medium-cost supplies. The prospects of yet another defensive emergency has also prompted investigations such as that carried out in the United States by the President's Materials Policy Commission (*Paley Report*) which was published in 1952. In graphic fashion it forecast prospective deficits between United States consumption and mineral production based on internal sources of supply. By attempting to look ahead over a quarter century, it also cast a new light on investment prospects in related types of economic activity. Various large American mineral-using industries, concerned about the longer-run supply situation, began to look elsewhere. Canada, being closest to hand and also one of the most politically stable of the lesser developed countries, was bound to receive a good deal of attention.

In the belief not only that Canada is a more reliable source of supply, but also that minerals will continue to enjoy a high priority in entering

dollar-short markets overseas, investors in the United Kingdom and Western Europe have also been reviewing the Canadian scene. Several such corporations, like the United States companies before them, have recently obtained large territorial concessions in Newfoundland, Labrador, Quebec and British Columbia.

More aluminum smelting capacity is also being built in this country by overseas interests. This and such metals as copper, lead, zinc, nickel and iron will therefore comprise a substantial proportion of Canadian exports across the Atlantic between now and 1980.

Assured of expanding markets, the nation's mining industry is entering yet another stage in its history. Soon its dependence upon a comparatively few mines will be a thing of the past. No longer will the deposits of the Sudbury area in Ontario, around Noranda and Thetford Mines in Quebec and in the Kootenay district in southeastern British Columbia account for the bulk of the nation's output of all minerals. With the addition of uranium, iron, nickel and new copper mines in the Canadian Shield, lead and zinc in New Brunswick, potash on the Prairies and asbestos in Ontario and British Columbia, Canada's output of metals, fissionable materials and industrial minerals is beginning to approximate more closely the consumption pattern of some of the more highly industrialized countries of the world.

One might reasonably ask "Why, when the existence of some of the larger deposits was known or suspected 50 or more years ago, has it taken half a century for a reasonably well-rounded mining industry to become firmly established in this country?"[1]

The reasons are several in number. Often transportation facilities were lacking. If they existed, overland hauls to existing markets were both long and unduly expensive. Again, many of the earlier-known Canadian deposits, though large, were either too low in average grade or too complex to permit them to be mined and processed using techniques and equipment available at the time. With the passing years, however, markets have grown, transportation has become less of a penalty and modern mining and processing methods and equipment have generally favoured the production and treatment of minerals of a type which Canada has long been known to possess in abundance.

A lack of markets is the main reason why the Canadian mining industry has only recently begun to come into its own. Up until 1939, the capacity of mines elsewhere was generally in excess of the then world demand. Also, requirements—and this was particularly true of some of the lesser-known

[1]Asbestos was first discovered at Thetford Mines, Quebec, in 1877. The nickel-copper ores of the Sudbury district were uncovered during the construction of the first transcontinental railway in 1883. The famous Sullivan Mine at Kimberly, B.C., was staked in 1892. The occurrence of iron ore in Quebec-Labrador was initially noted by federal government geologists in 1896. Dominion surveyors investigating iron ore deposits from the shores of Steep Rock Lake noted significant iron bearing formations there as early as 1903.

by-products—were small in relation to present rates of consumption. This meant that a comparatively few properties, favourably located with respect to the world's industrial markets, were able to supply the majority of their needs.

With new continental areas being opened up, new mines close to the world's main transportation routes were in a favoured position. Those which were relatively high in grade and limited in extent were quickly mined out. Others, because of their considerable size, or because advances and technology have permitted much lower-grade materials to be mined, are still supplying a goodly proportion of the world's mineral needs.

Even the United Kingdom had mines of her own in the 19th century, many of which were capable of meeting a large part of that country's domestic needs. What Britain, and later the other industrial countries of western Europe, could not produce locally, they were generally able to obtain from such nearby sources as Scandinavia, Spain, North Africa and the Balkan States. The United States', South American and Australian mines began first to play a supplementary role; then, as the years passed, they became more and more important as suppliers of minerals to the more industrially advanced countries of western Europe. In this, the United States forged rapidly to the front. Selling copper, lead, zinc and silver to world markets, the mining industry of the West, from the 1880's until the outbreak of World War II, led most other countries both in production for home use and for international trade. Meanwhile, activity south of the international boundary, based on extensive reserves of iron ore, phosphate rock, salt and elemental sulphur, helped to raise the United States to a leading position among the world's major industrial powers.[2]

Faced with such competition, it is little wonder that capital was difficult to obtain for the development of Canadian mines. Indeed, the first stumbling block (and one which has by now been largely removed) was the procurement of sufficient funds with which to carry out initial development, the unravelling of frequently complicated metallurgical problems, and the provision of suitable means whereby the output of Canada's considerable mine potential could be moved to market.

To British capital, the possibilities offered by the gold fields of the Rand, diamonds in South Africa, railroads in the Argentine, tea plantations in

[2]Having received its first real stimulus from the discovery of gold in California in the 1850's, the search for minerals in the United States turned rapidly inland. Soon the relatively small copper and other base metal mines of the east began to be supplanted in importance by much more impressive discoveries on the Great Plains and in the Rocky Mountain states. During the 1860's, considerable quantities of copper were produced in northern Michigan. Silver in unprecedented amounts was obtained from the famous Comstock Lode in Nevada during the 1870's. The extensive occurrences of zinc still being mined in the Tri-State area where Missouri, Kansas and Oklahoma come together, were uncovered about the same time. By the mid-1880's, the great hill of copper ore of Butte, Montana was the scene of considerable activity. This was soon to be followed by large-scale operations in the recovery of lead and silver in such other mountain states as Utah, Nevada and Idaho. By the turn of the century, iron ore was being mined in considerable quantities from the Mesabi iron range west of Lake Superior and the first phosphate mines in Florida were beginning to move their production out to markets both in the United States and abroad.

India and tin in the Malayan States generally looked much more attractive. The United States, a debtor nation as late as World War I, meanwhile was in an export surplus position. Preoccupied with the task of developing resources much closer to hand and rarely having access to markets commensurate with that country's own mine potential, the American mining and mineral-using industries also had little incentive to look to Canada for their future requirements.

Though markets were slow in developing and capital relatively scarce, there were other, and sometimes even more important, determinants of growth. Vast areas of Canada lay unexplored until the advent of the airplane in the early 1920's. Many of the techniques, such as block-caving and the use of mechanical cutting and loading equipment which have encouraged the non-selective mining of large and frequently low-grade ore bodies, are also developments of the past 30 or 40 years. The use of electric power, not only for lighting but also to drive ore-breaking and loading equipment, underground locomotives, hoisting and air-conditioning equipment as well as surface transport, dates from about World War I. Mucking machines, better quality drill steels, lightweight rock drills and the use for the first time in the 1930's of detachable drill bits, has also served to speed up operations and to reduce the Canadian mining industry's dependence upon what has continued to be one of its scarcest factors of production—skilled mining labour.

Equally impressive has been the introduction in recent years of heavy diesel-powered, earth-moving equipment. The early steam engine, dependent upon coal, has been effectively replaced by bulldozer tractors, carryall scrapers, continuous belt conveyors and giant diesel trucks, all of which could be driven by the much more transportable liquid fuels. Similar equipment has also permitted stripping operations to be carried out at greater depths. Small versions are finding their way underground. Not only are they continuing to reduce on-site employment, but they have also aided, through the economic recovery of progressively lower-grade ores, in first making profitable and then extending the useful life of many of Canada's more important mines.

Developments on the chemical and metallurgical fronts have similarly assisted in the opening up of major areas of production in this country. The very complexity of the more important Canadian ore bodies prevented their early exploitation. Instead of consisting largely of oxides or sulphides of one of the principal metals, the larger Canadian deposits were frequently found to contain two or more metals, intimately associated and containing appreciable quantities of such elements as gold, silver, tin, platinum, selenium, etc., disseminated more or less uniformly throughout their entire length and breadth. Potential mines of this character therefore presented, not one, but a whole series of metallurgical problems, the solution of which can now be

listed as among the more notable triumphs of Canadian engineering skill and enterprise.

Scientific progress has, in this way, made possible the treatment on site and in the world's major areas of consumption, what otherwise would still be regarded as marginal or sub-marginal ore. It has also made possible giant, integrated operations controlled by firms whose fortunes are no longer dependent upon the demand for any particular metal or other mineral. A variety of output, in other words, has become one of their major strengths. Thus applied technology has added an air of permanence to Canada's mining economy. The day of the short-lived boom town barely dawned in this country. In its place are relatively small though prosperous looking communities whose existence is predicated upon mines whose remaining life can properly be measured in decades rather than years.

Chemistry did not begin to play an important role in the recovery of metal values until the cyanidation process was introduced in the 1890's. This was put to use almost at once for the extraction of gold from the oxidized surface deposits characteristic of the Rand in South Africa. Unlike the so-called free milling ores, in which gold appears in metallic form, they had not lent themselves readily to amalgamation with mercury. Cyanidation, once proven, also turned out to be the key with which the treasure house of finely disseminated gold ores characteristic of some of the northern areas of Ontario and Quebec could be unlocked.

The use of cyanamide chemicals also assisted in the recovery of another precious metal, namely silver. They were used in the treatment of the silver-cobalt ores recovered from the Cobalt deposits during the early stages of this Ontario camp's existence immediately prior to World War I. As the grade of the original material declined, gravity concentration and finally flotation was used to extend a life of the extremely rich but highly localized ore bodies. Thus began the first of a series of developments which led to the establishment of hard-rock mining in this country as a permanent feature of the Canadian economy.

The success of the flotation process for the separation of ore from waste rock and, subsequently, one mineral from another, has also had much to do with the success and progressive integration of mining and mineral processing in Canada. Tailored to the particular characteristics of each mine, it has made the treatment of ore from the more complex deposits a less arduous task. On the other hand, it has tended to sever the link which previously existed between the nation's mines and the further processing of their ores and concentrates. By efficiently separating out the metal and other values, and by rejecting the gangue and other waste material it has permitted the higher unit value products to be transported over considerable distances to smelters and refineries engaged in the next stage of manufacture.

Selective flotation was first used extensively in the 1920's at Kimberly, British Columbia. There it was used to separate lead and zinc from the recalcitrant ores of the famous Sullivan mines. A few years later at Sudbury, Ontario, similar techniques were used to separate copper from nickel ore and to recover such elements as platinum as useful by-products. Sink-float plants have subsequently been installed close to many another mine in Canada. Differential flotation has also assisted the nation's producers of gold and other precious metals. Eventually it may be applied successfully to the recovery of uranium oxide. Thus, flotation based on the use of chemical agents has become far and away the leading method by which mineral ores are concentrated in this country.

In order for a mine to become a commercial proposition it may, at times, be necessary to smelt and refine its ores close to their source. This is generally true of gold and silver. Often it applies to copper as well. An adequate supply of energy is therefore one of the determinants of economic feasibility. Pyro-metallurgical processes, if they are to be successful, presume the availability at reasonable prices of a good quality of coking coal. Hydro-electricity must be available in substantial quantities and at a relatively low price if it is to be employed in the electro-processing of metals. Natural gas or an assured supply of residual oil is a prerequisite of the chemical type leaching processing now being used to an even greater extent as a means of separating out and purifying the mineral elements. Historically, only water-power has been locally available in the amounts required and at costs which tended to favour the further processing of Canadian produced minerals in this country.

Soon after electrolytic refining gained commercial recognition in the 1880's, it found application in Canada. In 1901 imported alumina began to be refined into aluminum ingot at Shawinigan Falls, Quebec. By 1903 the world's first electrolytic lead plant was in operation at Trail, B.C. Then, as one after another of Canada's mines joined the ranks of the permanent producers, other and even larger refineries were built in this country. World War I saw the construction of an electrolytic zinc line at Trail in 1916. Following investigations by the Ontario and federal governments, a nickel refinery was also constructed at Port Colborne in 1918. Like most of the others, the purpose of this plant was to treat smelter products which had previously been exported from this country as mixtures of metal values in their comparatively unprocessed state.

Though its beginning can be traced back to around the turn of the century, smelting and refining did not reach major proportions in Canada until the late 1920's. Then, encouraged by the expansionist thinking of the times, the first plants were enlarged and a number of new facilities were constructed. Copper refineries were built at Copper Cliff, Ontario, and at Montreal East in 1930 and 1931. The refining of zinc began at Flin Flon in

northern Manitoba in 1932. Radium concentrates originating in the Canadian Northwest Territories began to be processed at Port Hope, Ontario, about 1935. These ventures, together with further additions to the nation's aluminum, nickel and lead refining capacity, converted Canada from a major exporter to a principal importer of minerals in their raw or unmanufactured state.

Unlike imported coal or Canadian produced hydro-electricity, natural gases only recently began to be employed for processing in the extraction of metals and other values in this country. The first instance consisted of the pressure leaching of Lynn Lake nickel-copper ores in the early 1950's.

Having previously been mined and concentrated in northern Manitoba, they are now moved in considerable volume to a new gas-fed ammonia leaching plant near Edmonton. There, as in the case of the lead-zinc smelter at Trail, fertilizer chemicals are being produced as by-products of this treatment. The main objective, however, is to effect a high degree of recovery of the various metal values contained in the original concentrates. Quite likely modified processes of this kind will find increasing popularity in the treatment of other metal ores which are also amenable to chemical methods of treatment at ordinary or elevated conditions of temperature and pressure.

While the Canadian mining industry for a long time lacked markets and was confronted with serious metallurgical problems, it also had to combat the effects of distance. For the most part, discoveries of minerals have taken place in sparsely settled areas where surface transportation has rarely been available. The question has then arisen as to how these new properties might best be serviced. The answer has differed depending upon the nature of the mineral in question and the degree of processing which has been deemed necessary in each case.

The extraction of such high-value, low-volume products as gold and silver has not always required the construction of a rail line or even a highway. Like the uranium mines, these may be serviced by air. Thus it happens that the precious metals, and more recently uranium, have fulfilled a pioneering role in the development of Canada's northland.

By contrast, such low-value bulk minerals as iron ore can tolerate little in the form of transportation costs. Rail hauls must be kept to a minimum and water movements, because of their lower unit costs, are preferable. This is the main reason for the major iron ore developments bordering on the Great Lakes or involving properties located close to tidewater on the Gulf of St. Lawrence or on islands off the west coast of British Columbia. Such structural or industrial minerals as gypsum, salt and potash exhibit similar characteristics where locational advantage is concerned.

Most of the non-ferrous metals are in an intermediate category, as their bulk can be substantially reduced by concentration at, or close to, the mines themselves. On-site smelting and refining is not usually economic. While it further reduces the volume of outward movements, it also necessitates the bringing in of additional machinery and equipment, certain heavy chemicals and a wealth of other supplies. A much larger townsite must be established; thus rail connections are usually called for. Only in a few cases has highway transportation so far proven adequate to service integrated mining and processing developments in Canada and elsewhere.

A cold climate has imposed additional costs. Plants, offices, homes and other accommodation have had to be better built. Heating outlays have become an appreciable item of expenditure. Special means for handling and transporting ores have had to be developed. Inventory charges have been higher in circumstances where water transport can operate only on a seasonal basis. Besides, a good deal of money has had to be spent both by government and by the industry in keeping lines of communication and transport open the year round.

The extent of these expenditures must not, however, be exaggerated. Equal, at most, to several per cent of the industry's gross value of sales, they are far outweighed by labour costs and prices paid for machinery and equipment.

Other influences of a more favourable character can, of course, be enumerated. Yet, like technical competence and political stability, they tend to be more of a qualitative nature. Rather than pursue this line of thought, let us turn to a more systematic appraisal of the physical environment in which the Canadian mining industry has had to and must evolve.

3

THE PHYSICAL SETTING

Introduction

It is useful at this stage to present a general picture of the main geological features of Canada and to describe, in a general way, the distribution of mineral deposits presently known and likely to be discovered in the future. Couched in language familiar to the economic geologist, it is also intended to provide a physical background against which the more detailed commodity market and resource development studies can be viewed in their appropriate national and world perspectives.

A. Physical Features

Canada is naturally divided into five main regions. (See map entitled Canada Showing Main Geological Regions.) Each has characteristic geological features which substantially determine the mineral potential of the provinces and territories in which they occur.

The *Canadian Shield,* forming nearly half of Canada, is the largest of these. It is saucer-like in shape, sloping gently toward the central depression of Hudson Bay, around which it lies only a few feet above sea level. Nearly all the Shield is less than 2,000 feet above sea level, and over most of this great area the local relief is less than 200 feet. However, in northwest Labrador the Torngat Mountains rise 5,000 to 6,000 feet and on Baffin Island mountains rise 8,000 to 10,000 feet above the sea. Over the greater part of the Shield, intense glaciation has left scattered rounded rock outcrops separated by glacial deposits, muskeg and myriads of lakes of many sizes and shapes, connected by streams and rivers interrupted by many rapids. Rock exposures probably total less than 10% of the surface. The northern part of the Shield lies beyond the northern limit of trees and the ground is permanently frozen except for a thin surface layer that thaws each summer.

The *Plains Region* includes the Interior Plains, the St. Lawrence Lowlands, the Hudson Bay Lowlands, and the plains and plateaus of the Arctic

Islands. The Interior Plains flank the Canadian Shield on the west and extend north from the United States border to the Arctic Ocean. Their gently rolling surface, broken only by rare escarpments and hills, slopes imperceptibly upward and westward from the Shield until, at an elevation of about 4,000 feet, they merge with the foothills of the Cordilleran Region. The southern part of the Interior Plains is an almost treeless prairie that forms one of the greatest agricultural areas of North America.

The *St. Lawrence Lowland* borders the Canadian Shield on the south between Lake Huron and Quebec City, except near the outlet to Lake Ontario where it is interrupted by a southerly tongue of the Shield known as the Frontenac axis. West of this axis the rolling surface of low relief slopes gently southwesterly, broken only by the prominent Niagara escarpment.

The *Hudson Bay Lowland* is a low swampy plain sloping gently upward from the southwest shores of Hudson and James Bays.

The *Arctic Islands* are in places rolling treeless lowlands or plains sloping gradually to the sea but, in the eastern part particularly, sea cliffs rise

abruptly 500 to 1,500 feet to deeply incised plateau-like surfaces which attain still greater heights inland.

The *Cordilleran Region* lies between the Interior Plains and the Pacific Ocean. It includes three northwesterly trending units: a western system of mountains; a central system of plateaus and mountains; and an eastern system of mountains. In British Columbia, the central and eastern systems are separated by a deep and persistent valley called the Rocky Mountain Trench. The highest peaks of the Canadian Cordillera are up to 12,000 feet except in the St. Elias Mountains of northern British Columbia and Yukon where Mount Logan rises to 19,850 feet and several others are only slightly lower. The mountains of the eastern Cordillera, which include the Rockies, present a general sawtooth appearance, whereas in the ranges of the western Cordillera in many places, jagged peaks are interrupted by more rounded, or fairly level upland surfaces. The valleys are forested except some in the far north, but innumerable peaks rise well above the timber line. Parts of the Yukon are underlain by permanently frozen ground. Snowfields, icefields and alpine glaciers are common, particularly near the coast where some valley glaciers extend to, or nearly to, sea level.

The *Appalachian Region* lies southeast of the Canadian Shield and east of the St. Lawrence Lowlands. It is a broad belt of mountainous country that occupies the Atlantic Provinces and the island of Newfoundland, Gaspé, and part of the Eastern Townships of Quebec. The highest hills are found in the Shickshock Mountains of Gaspé Peninsula which rise to heights of more than 4,200 feet above sea level. Elsewhere only a few mountains and uplands exceed elevations of 1,500 to 2,000 feet.

The *Innuitian Region* extends south and west from Ellesmere Island to Melville Island in the northern Arctic. It consists of mountains rising to 10,000 feet and in places the belt is more than 200 miles wide.

B. Geology and Mineral Deposits

(a) The Canadian Shield

During the long ages of Precambrian time, great accumulations of lava flows and sedimentary strata were formed in what is now the Canadian Shield. These volcanic and sedimentary rocks were subjected to mountain building processes during which they were steeply folded and faulted, and large bodies of granite and other igneous rocks were formed in the roots of the mountains. These ancient mountain ranges were worn down by erosion, seas encroached on the resulting lowland and the cycle of deposition, mountain building, granitic intrusion and erosion began again. This cycle was repeated many times during the immensely long Precambrian time. As a result of this long and complex history the Shield now consists mainly of granite and granitoid gneiss with relatively small areas of steeply folded volcanic and

sedimentary rocks scattered through it (see map 900A, in pocket). The region has been a stable mass since Precambrian time.

The Early Precambrian (Archaean) strata occur as isolated troughs and basins of severely deformed and altered volcanic and sedimentary rocks in the predominant granitic rocks of the Shield. Some of these belts are more than 100 miles long and many miles wide. They are older than the surrounding granites and represent remnants of former extensive formations that were partly destroyed by granitic intrusions and partly removed by erosion. The common rock types include basic volcanic flows now altered to greenstones, banded chert with iron oxide (iron formation), impure quartzite (greywacke), and slate. In places volcanic rocks predominate; elsewhere the sedimentary formations are the more abundant. Before the end of Early Precambrian time these ancient formations were steeply folded by mountain building processes, their roots intruded by granitic rocks, and the mountains worn down by erosion to expose the granitic rocks in their roots.

Resting on the upturned edges of these ancient formations and on some of the granites that intruded them are extensive sheets of relatively undeformed or flat lying volcanic and sedimentary rocks of Late Precambrian (Proterozoic) age. The Late Precambrian differs from the Early Precambrian in being made up largely of sandstones, quartzites, limestones and dolomites. In places the Late Precambrian rocks are cut by granitic intrusions and by dykes and sills of diorite and gabbro (diabase).

A complex of granitized sedimentary gneisses associated with large amounts of crystalline limestone makes up the southeastern part of the Shield which is known as the Grenville subprovince. The age of the Grenville rocks is uncertain but recent work suggests they are of Late Precambrian age.

The known and potential mineral resources of the Canadian Shield are larger and more diverse than those of any of the other geological regions of Canada. There are, however, no mineral fuels. In 1955, about 77% of Canada's total metal production was mined from the Canadian Shield. In that year it yielded 88% of the copper, 92% of the gold, 83% of the iron ore and all of the nickel, platinum and platinum group metals, uranium and cobalt produced in Canada. Nearly all the mines in the Shield lie within 300 miles of its outer margin. Without doubt this distribution is the result of the relative accessibility of the outer fringe, and consequent more thorough geological mapping and prospecting. We may reasonably expect that the distribution and abundance of ore deposits in the central, less accessible parts of the Shield will be found to be similar to that in the more thoroughly explored fringe.

Most of the deposits of metallic minerals lie within the troughs, basins and other remnants of Early and Late Precambrian volcanic and sedimentary rocks in the widespread granitic rocks that make up most of the Shield. As already indicated, erosion in Early Precambrian time cut down to the roots

of the ancient mountain systems. Consequently, the mineral deposits in Early Precambrian rocks are types formed at great to intermediate depths in the earth's crust. These include gold quartz veins, large copper-zinc deposits, quartz veins containing tungsten, and pegmatites containing beryllium and lithium. Many of the mines are deep because in Canada, as in other parts of the world, deposits in Early Precambrian rocks continue, on the average, to much greater depths than do those in younger rocks.

Another group of distinctive ore deposits is associated with the Late Precambrian rocks. This group includes the great copper-nickel-platinum deposits at Sudbury and the silver-cobalt ores of Cobalt. Late Precambrian lava flows contain copper in many areas. Most of Canada's iron ore deposits and potential deposits are in Late Precambrian formations in Labrador, northern Quebec and western Ontario. A variety of uranium deposits of substantial size has been found and developed during recent years in Late Precambrian rocks along the western and southern borders of the Shield. They occur as hydrothermal vein deposits and as disseminated pitchblende in or near fault zones at Great Bear Lake and Lake Athabasca, and as part of a quartz-pebble conglomerate in the Blind River area north of Lake Huron. The latter deposits rank among the largest known reserves of uranium in the world.

The Grenville subprovince, in the southeastern part of the Shield, contains a somewhat different assemblage of mineral deposits. Valuable mica and feldspar deposits are found in some of the abundant pegmatites; graphite is common in the crystalline limestone and has been mined; contact metamorphic magnetite iron ore bodies are being mined and others prepared for mining; uranium ore bodies associated with certain unusual pegmatites are being brought into production; brucite, $Mg(OH)_2$, is being mined from Grenville limestones for the manufacture of refractory brick and as an ore of magnesium; nepheline syenite is being mined on an increasing scale for the manufacture of glass and ceramic materials; and dolomite is being mined as an ore of magnesium. In addition, large reserves of ilmenite, an ore of titanium, associated with the anorthosites of southern Quebec, and potentially productive deposits of niobium (columbium) have been found recently in complexes of carbonate and alkaline rocks near Montreal and north of Lake Huron.

(b) Plains Region

The Plains Region is underlaid by sedimentary strata that range in age from Cambrian to early Tertiary or younger. They overlap the Shield on all sides except the northeast. In general, the strata dip very gently away from the Shield. They have not been affected by mountain building forces and, with minor exceptions, are not intruded by igneous rocks. The Plains Region is cut off on the north, west and southeast by mountain systems.

The strata underlying the Plains include sandstones, shales, limestones and dolomites. Most of the beds were deposited in seas of moderate to shallow depth. However, in some of the more recent periods fresh or brackish water deposits accumulated in considerable volume. Probably some of the Palaeozoic and Mesozoic strata formerly extended over large areas of what is now the Canadian Shield but have been removed by erosion.

The most important known and potential mineral deposits of the Plains are oil, natural gas, coal and recently discovered potash salts; other characteristic deposits include common salt and gypsum and construction materials. The St. Lawrence Lowlands and Interior Plains of Manitoba, Saskatchewan, Alberta and British Columbia have been extensively explored, particularly in the last ten years, but it will be many years before exploration is completed. Much less work has been carried out in the Interior Plains of the Northwest Territories and Yukon although they also are favourable for the occurrence of similar valuable deposits.

The value of crude petroleum produced in 1955 amounted to about 17% of Canada's total mineral production. Nearly all of this came from the Interior Plains although some was produced from the St. Lawrence Lowlands. In 1955, about 30% of Canada's coal production came from the Interior Plains.

The Interior Plains of central Alberta contain the largest known oilfields in Canada. The oil is found in beds of Upper Devonian, Mississippian, and Lower and Upper Cretaceous age. Large reserves of natural gas in Alberta and northeast British Columbia are ample to permit export by pipeline to metropolitan areas in eastern Canada and the Pacific coast. Bituminous sands of Lower Cretaceous age outcrop for 118 miles along the Athabasca River in the Fort McMurray area of Alberta and form a great reserve from which petroleum and other products may some day be obtained. Extensive and readily accessible coal deposits occur in Cretaceous and Palaeocene rocks of the Plains of western Canada. Common salt and gypsum are abundant in various places in Silurian and adjacent strata. Very large deposits of the potassium salts, sylvite and carnotite, have been discovered recently in Devonian strata in Saskatchewan and are currently being developed.

Millions of tons of lead-zinc ore have been found in Middle Devonian dolomite near Pine Point on the south shore of Great Slave Lake and minor occurrences of the same minerals are known in similar rocks in many places in the Plains.

(c) Cordilleran Region

The Cordilleran Region includes all mountain built strata, including the foothills, west of the Interior Plains. It extends northwestward through Canada, embracing most of British Columbia, a small part of Alberta, the

Yukon, and a small part of the Northwest Territories. The region is on the site of a great basin of sedimentation where seas and fresh water basins existed during much of the time from Late Precambrian to Late Mesozoic and Early Tertiary.

The mountains of the western Cordillera are carved in a complex of sedimentary, volcanic and plutonic rocks. Great thicknesses of sedimentary strata are exposed that range in age from Late Precambrian to Early Mesozoic. Lava flows and volcanic fragmental rocks, mainly of Late Palaeozoic and Mesozoic age, are interbedded with them. These strata were folded and intruded by granitic rocks, mainly in the Mesozoic era. The mountains formed at that time were eroded to expose the granitic rocks in many places —in particular the large and complex coast range batholith along the western mainland of British Columbia. Tertiary lava flows were poured out, followed by uplift of the region and Late Tertiary dissection.

The mountains of the eastern Cordillera were formed from a great thickness of sedimentary strata ranging in age from Late Precambrian to Tertiary. The strata consist chiefly of limestone, quartzite and shale and, in the Rocky Mountains, have a total thickness estimated at 68,000 feet. Sedimentation continued until Early Tertiary time, long after the main period of folding in the mountains to the west (western Cordillera). The Rocky Mountains and other ranges of the eastern Cordillera are still in the first stage of erosion which accounts for their characteristic sawtooth appearance. With minor exceptions, they do not contain igneous intrusions.

Numerous mineral deposits are known. In 1955 the Cordilleran Region was the source of about 51% of the silver, 86% of the lead, 51% of the zinc, 6% of the asbestos, all the antimony and nearly all the tungsten mined in Canada. It was also the source of substantial amounts of coal and oil. Most of the productive and known mineral deposits are in southern British Columbia, southwestern Alberta and northwestern British Columbia and southwestern Yukon. This distribution is probably the consequence of the longer and more intensive search that these more accessible areas have received.

The western Cordillera has been folded, faulted, intruded by igneous rocks of several ages and deeply eroded to expose these intrusions and the mineral deposits associated with them. It contains a large variety of metallic mineral deposits formed under widely different conditions of temperature and pressure. They include in particular silver, lead, zinc, and copper but also mercury, iron, tungsten and gold. Asbestos in ultrabasic intrusions in northern British Columbia has been discovered recently and is being mined. Substantial coal deposits occur in basins of Lower Cretaceous, Upper Cretaceous and Tertiary age.

The eastern Cordillera, although highly folded and faulted, has not undergone sufficient erosion to expose deep-seated granitic rocks and their

associated metallic mineral deposits. However, geological conditions, mainly along the eastern foothills, have been favourable for the development of important deposits of coal, oil and gas. Most of the coal being mined comes from Lower and Upper Cretaceous beds but some is from Tertiary strata. Some of the Cretaceous formations have been folded sufficiently to raise the grade of the coal to high bituminous rank. Petroleum and natural gas are found in four major fields, three in the southern foothills of Alberta and one in the Mackenzie River valley. One of the former, Turner Valley, in its peak year in 1942, was the largest producer in Canada.

(d) Appalachian Region

The Appalachian Region is underlaid by a highly folded and faulted assemblage of sedimentary and volcanic rocks ranging in age from Early Precambrian to Triassic. Extensive mountain building periods occurred at the close of the Ordovician period and in Devonian time; both disturbances produced structures that trend northwesterly. Intrusions ranging in composition from granite to peridotite are widespread; most were emplaced in Devonian time.

The Appalachian Region has been noted mainly for its non-metallic mineral deposits, coal, and iron ore. However, recent discoveries, especially in Gaspé, New Brunswick and Newfoundland, promise greatly to increase the relative importance of copper, lead and zinc. In 1955 the region produced about 61% of the coal (by value), 90% of the asbestos, 83% of the barite and more than 99% of the fluorspar mined in Canada.

The Pennsylvanian strata contain bituminous coal and the Mississippian deposits of gypsum, common salt, barite, petroleum, natural gas and oil shale. The Ordovician or Devonian ultrabasic rocks of the Eastern Townships of Quebec, Gaspé Peninsula and Newfoundland carry asbestos and chromite. Large deposits of copper, lead, and zinc in Gaspé Peninsula, New Brunswick and Newfoundland are believed to be related to Devonian granite intrusions. Oolitic hematitic iron ore deposits of sedimentary origin are mined from Ordovician rocks of Newfoundland. Manganese has been found in a variety of deposits.

(e) Innuitian Region

The Innuitian Region of the northerly Arctic Islands is underlaid by moderately to intensely folded rocks ranging in age from Precambrian to Tertiary. They consist mainly of sedimentary strata with some volcanic and metamorphic rocks. Granitic to ultrabasic intrusive rocks have been found in the northern part of the region.

Numerous occurrences of coal are known; they range in age from Devonian to Tertiary and are mainly of low rank. Anhydrite-gypsum is exposed

in the central parts of domes and folds at many places in the northwest part of the region. The region has not been prospected but geological conditions suggest that valuable accumulations of petroleum and gas may be found.

C. Conclusion

Most of Canada's mineral production is from mines within a few hundred miles either of tidewater or of the nation's principal transportation arteries; all but a small percentage comes from a westerly trending strip comprising the southern third of Canada. In contrast, the main geological regions of Canada trend northerly. There is no reason for believing that mineral deposits are less abundant or less rich in the northern parts of these regions. As they receive greater attention it is reasonable to expect that they, in turn, will contribute mineral wealth in volume and variety about equivalent to the more fully explored and accessible southern areas.

With Canada's economic frontiers moving both westward and northward, with new tools and techniques for the discovery of hidden ore bodies difficult or impossible to find by older prospecting methods, and with geological conditions in the northern, less explored regions as favourable as those in which most presently producing mines are located, Canada's mineral potential and future status as a world producer and exporter can be viewed with optimism.

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4

OVER-ALL GROWTH AND SHIFTS IN CANADIAN MINING, 1926-55

THE PAST 30-year period, 1926 to 1955, has witnessed many economic changes. Including four boom years, the Great Depression of the 1930's, six years of global war and a decade of nearly full employment, it has also placed unforeseen stresses and strains upon the Canadian economy. Domestic and export requirements have fluctuated first in one direction, then another. Yet, over all, it has been a period of rapid economic growth. Other trends can also be identified which may persist a decade or more into the future.

As measured in value terms, the most noticeable characteristic of Canadian mine output has been its erratic upward course. Persistent upswings in income have in turn been followed by sharp downward adjustments. Fortunately, the latter have been due more often to reductions in price than to diminutions in volume of output and employment. Various charts portraying these movements are included in this chapter. They also set out, much more clearly than the supporting statistical series are wont to do, the year-to-year variations which have taken place with respect to production, exports, imports and domestic consumption.

When reviewing this information, several important qualifications must be borne in mind. As this study deals primarily with hard-rock mining and metal processing, figures pertaining to the mineral fuels have been excluded. Coal, oil and natural gas are treated separately under the heading of energy and reviewed in the Commission's study *Canadian Energy Prospects*. Gold and iron, though in more limited fashion, are also exceptions to the rule. Exports of the former have not been included under the heading of "total mineral exports" because gold movements are generally taken to be currency rather than commodity transactions. Pig iron and steel production is not included as "primary manufactures" as the iron and steel industry has, for purposes of the Commission's various staff studies, been considered as falling under the heading of secondary manufacturing.

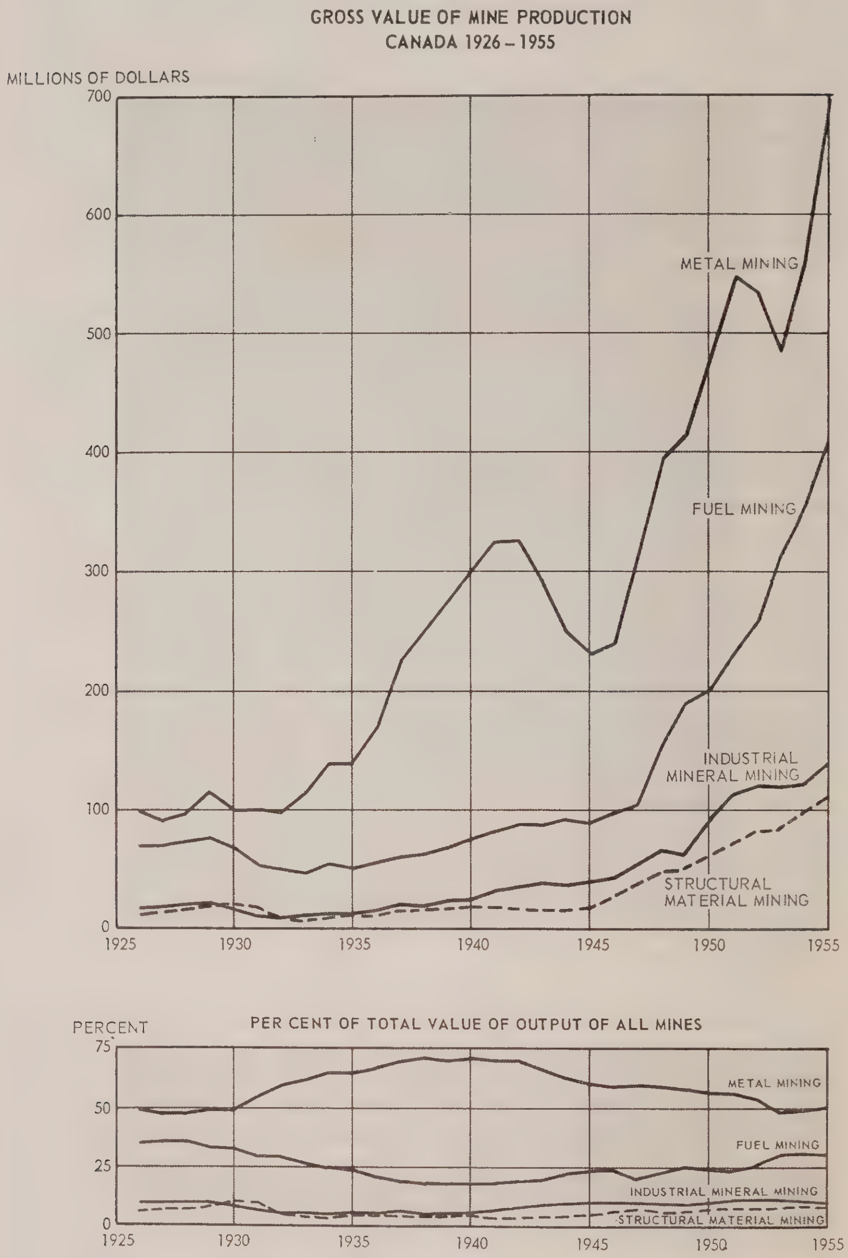
Our statistical researches reveal that the gross value of Canadian mine output has risen to approximately seven times the level achieved in the mid-1920's. (See chart entitled Gross Value of Mine Production, 1926-55.) Thirty years ago, it was in the vicinity of $200 million. Now it is in excess of $1.6 billion. Metal mining has been the major cause of this upswing. From nearly $100 million in 1926, it rose to about $700 million in 1955. Industrial minerals made a comparable advance, rising from $18 million to $145 million. Structural materials, meanwhile, have made up much of the ground they lost prior to 1946. The total value of cement, brick, stone, gravel, etc. produced in Canada is now in the order of $228 million. In 1929, it was only $20 million.

These statistics are significant only as the sum of their various components. The persistent decline in value of output which characterized the early 1930's, for example, is largely attributable to a falling-off in asbestos and cement requirements. As a result, industrial mineral output values fell by 50% and those of structural materials declined to a point 40% below the levels reported in the mid-1920's. Metal mining activity was more buoyant. Consequently, in the trough year 1934, these non-metallics accounted for as little as 9% of the value of all Canadian mineral production.

Among the metals, gold output was already on the increase. Indeed, it rose sufficiently rapidly after 1932 to offset a mild recession in non-ferrous metal sales. Early in World War II, it was also due to gold that the gross value of Canadian mine output changed direction. Then it began to move downward as a shortage of mine labour, together with a fixed price for gold, began to curtail Canadian metal production.

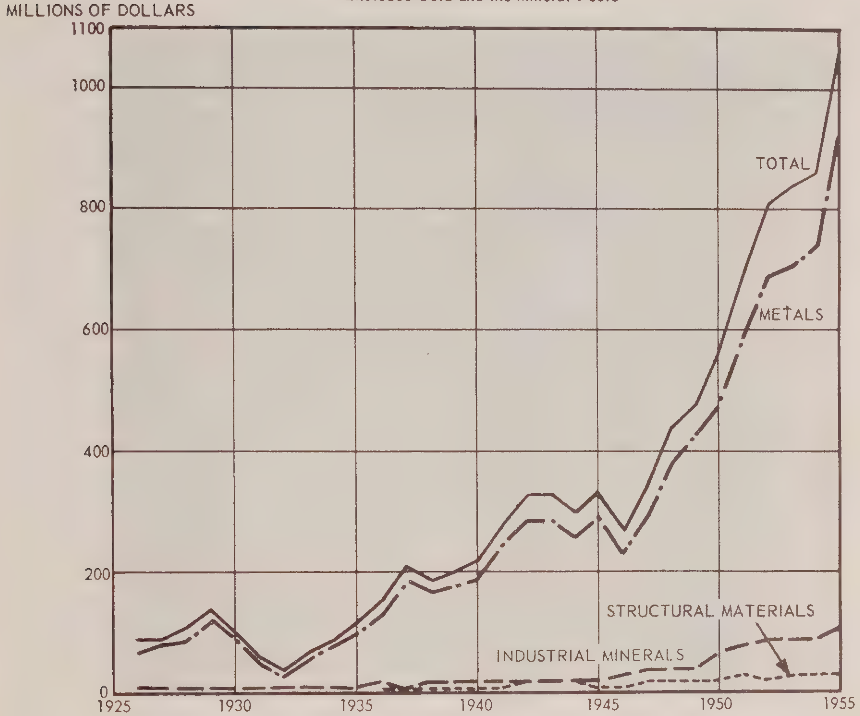
Since 1945, the over-all output curve has been generally upward. Prices also have risen in current dollar terms. Sharp upward adjustments in 1950 and 1951 followed a year or two later by price movements in the opposite direction have, however, caused the total value of metals produced in Canada to sag abruptly. Sales of industrial minerals, meanwhile, have tended to level off.

Due to the fact that the Canadian mining industry sells approximately 75% of its output in the United States, the United Kingdom and elsewhere, the export value curve tends to parallel that traced out by domestic production. (See chart entitled Value of Exports of Metals, Industrial Minerals and Structural Materials from Canada, 1926-1955.) Due to the fact that structural materials produced in this country are largely for home consumption, metals have been an even more important determinant of sales abroad. Nickel, copper, lead, zinc and aluminum have accounted for better than 75% of the nation's total earnings of foreign exchange on mineral commodity account. As for industrial minerals, asbestos and gypsum have been far and away the most important exported from Canada.

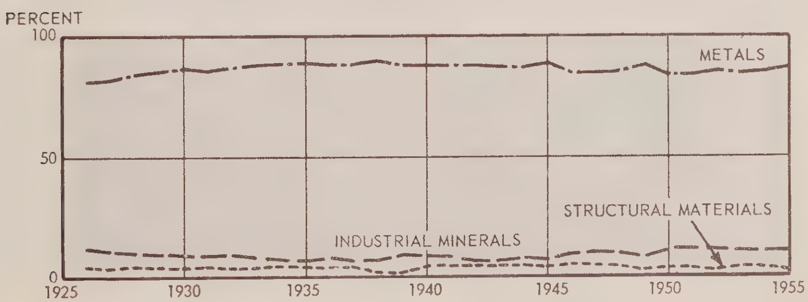

GROSS VALUE OF MINE PRODUCTION
CANADA 1926 – 1955
MILLIONS OF DOLLARS
700
600
500
400
300
200
100
0
1925
1930
1935
1940
1945
1950
1955
METAL MINING
FUEL MINING
INDUSTRIAL MINERAL MINING
STRUCTURAL MATERIAL MINING
PERCENT
PER CENT OF TOTAL VALUE OF OUTPUT OF ALL MINES
75
50
25
0
METAL MINING
FUEL MINING
INDUSTRIAL MINERAL MINING
STRUCTURAL MATERIAL MINING

VALUE OF EXPORTS OF METALS, INDUSTRIAL MINERALS AND STRUCTURAL MATERIALS FROM CANADA, 1926 – 1955 *

* Excludes Gold and the Mineral Fuels

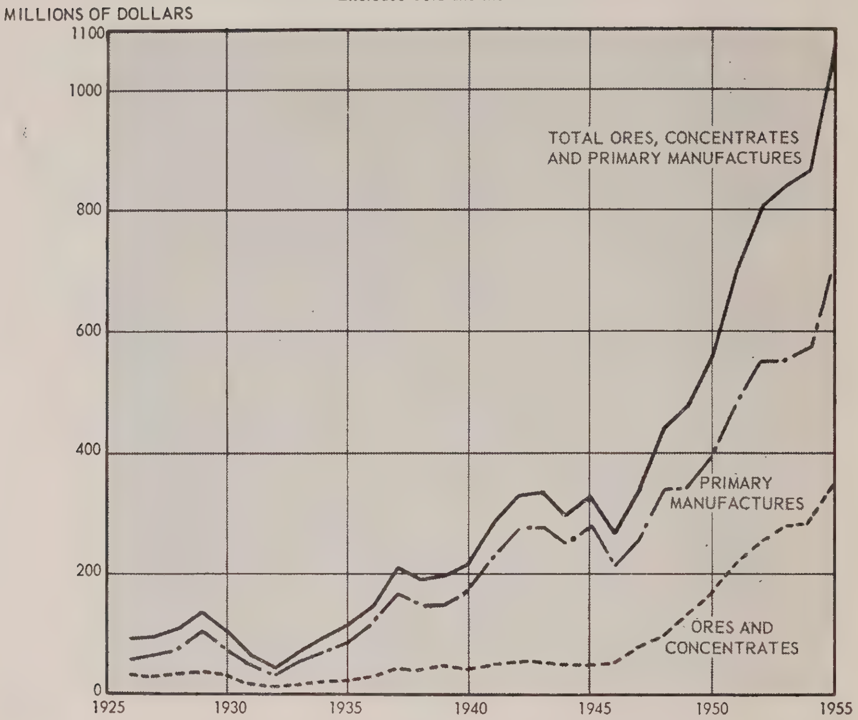


METALS, INDUSTRIAL MINERALS AND STRUCTURAL MATERIALS AS A PERCENT OF TOTAL

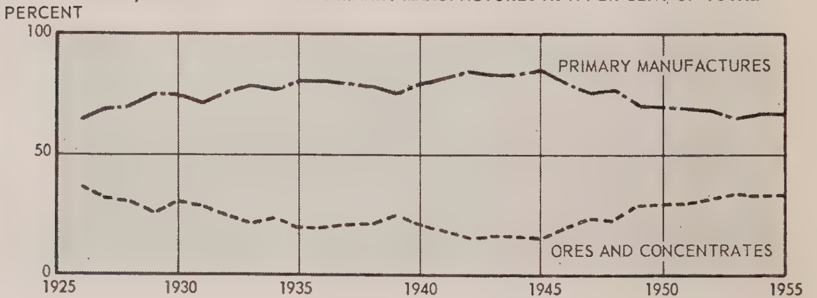


VALUE OF EXPORTS OF MINERAL ORES, CONCENTRATES AND PRIMARY MANUFACTURES FROM CANADA, 1926 – 1955*

* Excludes Gold and the Mineral Fuels



ORES, CONCENTRATES AND PRIMARY MANUFACTURES AS A PER CENT OF TOTAL

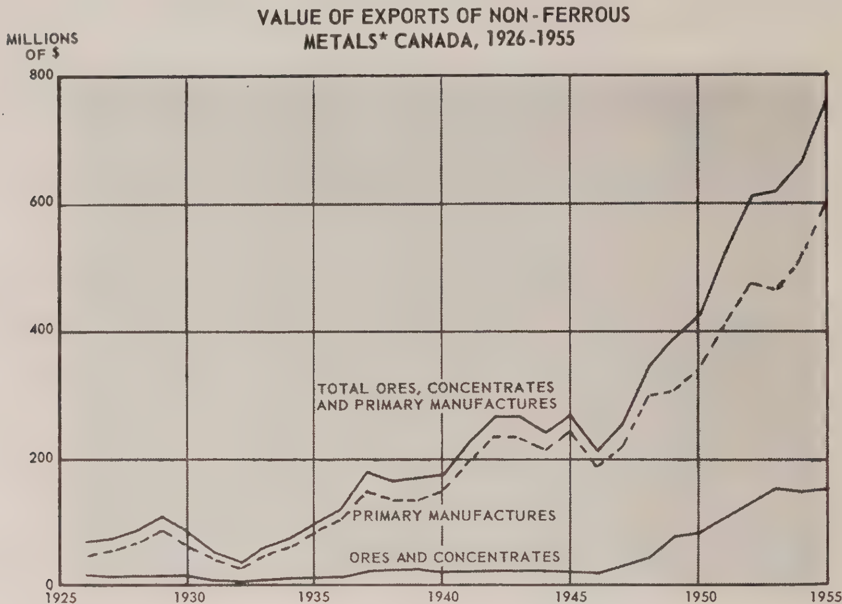


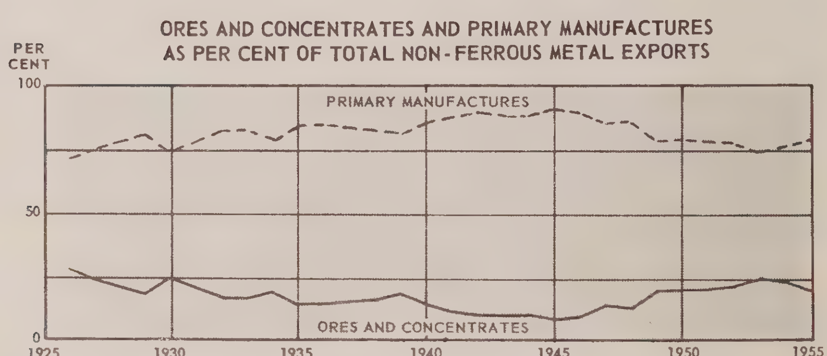
The extent to which these native resources have been processed prior to export is another matter of interest. In total, the value of ores and concentrates shipped abroad has never exceeded the value of primary manufactures marketed outside of Canada. This is to be expected as their value might at least have been doubled had they otherwise been converted into metal ingot or other semi-processed forms. Relative movements as opposed to absolute amounts therefore merit the greater attention. As a proportion of the total value of all mineral exports, ores and concentrates fell more or less persistently from 1926 to 1945. Since then, however, the proportion leaving the country in unmanufactured form has increased. From 36% in 1926, it fell to 15% in 1945. The latest figures (1955) show ores and concentrates accounting for 33% of all mineral exports.

Metal statistics in this connection are complicated by aluminum. Produced from imported raw materials and exported in metal form, it tends, arithmetically, to exaggerate the extent to which Canadian produced minerals are processed prior to shipment elsewhere. The over-all trend is also affected, as aluminum production has been rising more rapidly than Canadian mine output. On balance, and allowing for aluminum's behaviour relative to that of the other metal totals, it would appear that about 40% of Canada's mineral exports consist of raw or unmanufactured materials. Allowing for value added by processing, this is the same thing as saying that between one-half and two-thirds of Canada's mineral exports have been shipped directly from the mine to smelters, refineries and like manufacturing facilities elsewhere.

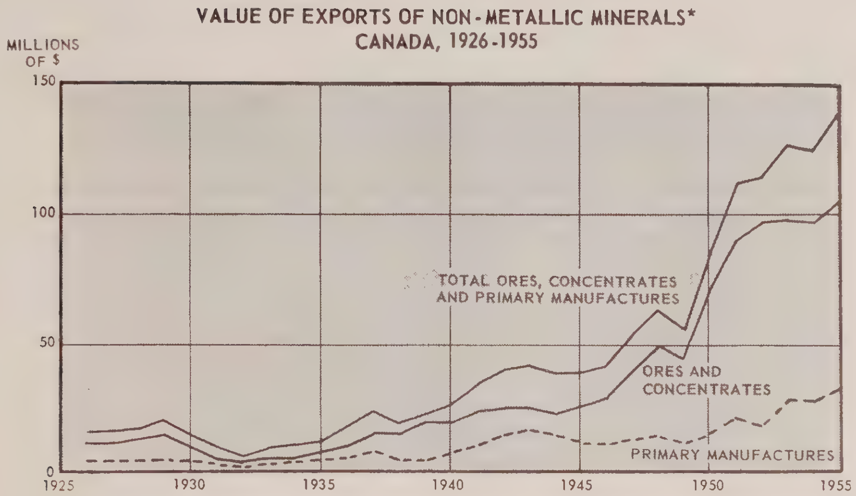
Canada's developing trade in metals is described graphically in the chart entitled Value of Exports of Non-Ferrous Metals, Canada, 1926-1955. As far as the industrial minerals (asbestos, gypsum, fluorspar, etc.) are concerned, processing in Canada is the exception rather than the rule. (See also chart entitled Value of Exports of Non-Metallic Minerals, Canada, 1926-1955.) Usually 75% or more of the total reported export value has consisted of ores and concentrates. Primary manufactures rarely exceeded one-third of the total and, in 1955, comprised 24% of the value of all industrial minerals sold abroad.

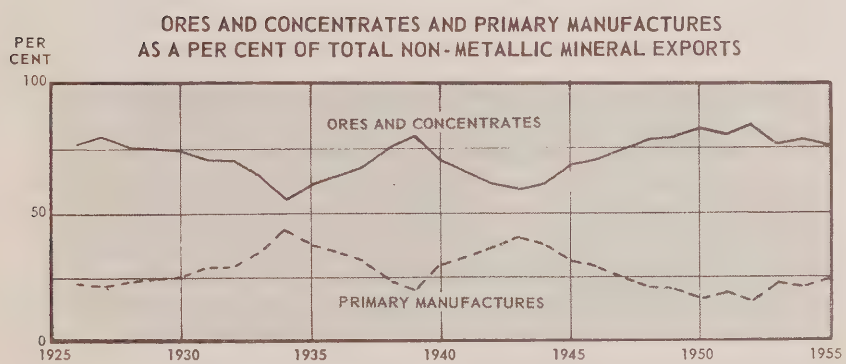
The movement, in value terms, of Canada's imports of minerals and mineral products, is illustrated in the chart entitled Value of Imports of Metals, Industrial Minerals and Structural Materials into Canada, 1926-1955. Like Canadian production and Canadian exports, the trend has been erratically upward. Yet it differs in that the over-all increase is modest by comparison. Ingots rose about fourfold from between the late 1920's and the early 1950's. Increased landings of bauxite (for aluminum production) and iron ore were chiefly responsible for this increase. Meanwhile, foreign deliveries of industrial minerals more than trebled, and structural material imports rose approximately tenfold.





* EXCLUDING GOLD
BUT INCLUDING ALUMINIUM.





* EXCLUDING COAL, NATURAL GAS, CRUDE OIL AND PETROLEUM PRODUCTS.

Most of this material, interestingly enough, enters Canada in the comparatively raw state. Mineral imports, in other words, have consisted more of ores and concentrates than primary manufactures. During World War II and again since 1945, there has been a fair margin between them. Only in the interwar period, and again in 1949, were they approximately equal in money terms. Currently about 60% of Canada's total imports of minerals are being shipped directly from mines in other countries. The remainder consists largely of non-ferrous metals in ingots, sheet, bar, rod, wire and strip form. (See chart entitled Value of Imports of Ores, Concentrates and Primary Manufactures into Canada, 1926-1955.)

As defined in this study, domestic supply is taken to be the sum of Canada's production and Canadian imports, less the value of ores, concentrates and primary mineral products exported to other countries. It is, therefore, a measure, exclusive of inventory changes, of mineral consumption here. Canadian requirements, judged in this manner, also appear to have risen considerably since the late 1920's. (See chart entitled Value of Domestic Supply of Mineral Ores, Concentrates and Primary Manufactures, Canada, 1926-55.) Domestic production plus imports less exports was valued at around $100 million 25 years ago. During the 1951-55 period, the corresponding figure was about $440 million. Expressed in value terms, Canadian mineral requirements have, therefore, risen to between four and five times their money equivalent of 30 years ago. Imports as a percentage of domestic supply, meanwhile, have varied considerably. Averaging out at around 35% in the late 1920's, they rose to more than 50% in 1945 and dropped back to 30% in 1955.

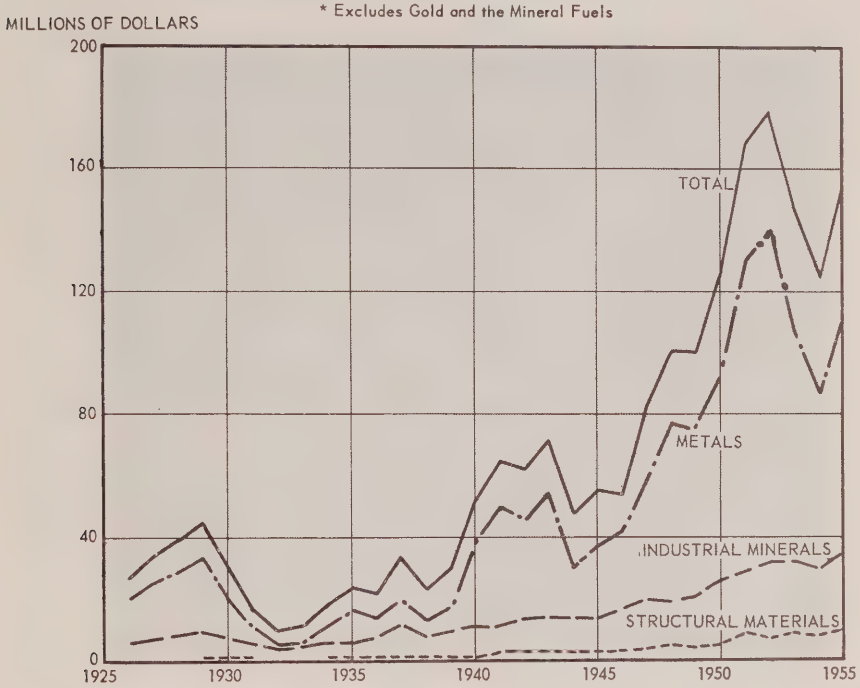
Over the past quarter century, Canadian output appears to have been gaining on domestic requirements. The mining industry in this country has therefore become even more dependent on export markets than it was 30 years ago. Imports, starting from a much smaller base, have meanwhile lagged somewhat behind the growth in home demand.

While the various series illustrated by the accompanying charts can be usefully compared one with the other, the fact that they are expressed in current (rather than constant) dollars should also be borne in mind. To the extent that they reflect inflationary price increases, they also tend to exaggerate the changes which have actually taken place over the past quarter century. In order to set these trends in their proper perspective, the annual values have been divided by the relevant wholesale price indices. The results more nearly approximate what has been happening in real or constant dollar terms.

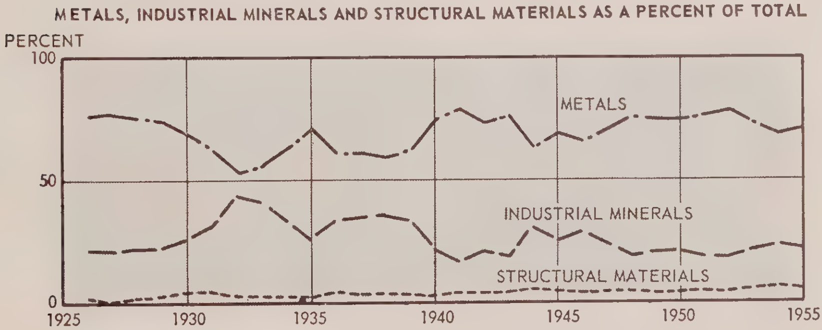
On reviewing the results of this arithmetic, we find that Canadian mineral production has risen to approximately three and one-half times the level achieved in the late 1920's. Exports, meanwhile, have increased approxi-

VALUE OF IMPORTS OF METALS, INDUSTRIAL MINERALS AND STRUCTURAL MATERIALS INTO CANADA, 1926 – 1955 *

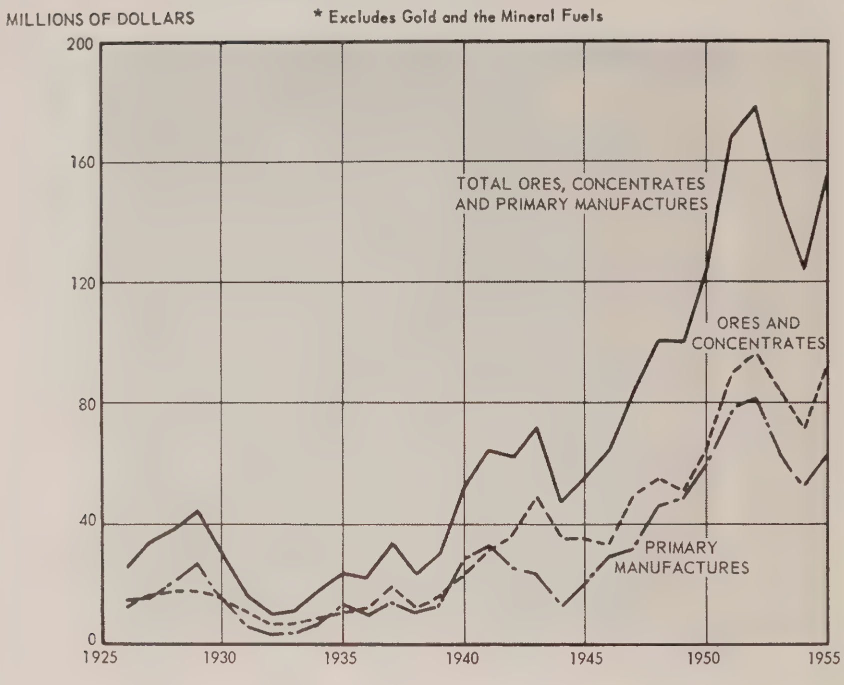
* Excludes Gold and the Mineral Fuels



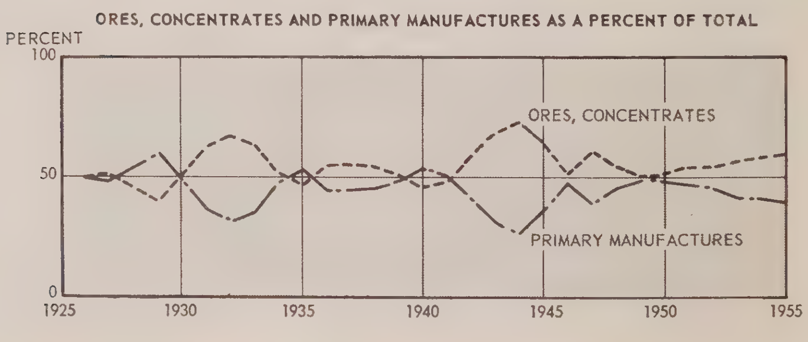
METALS, INDUSTRIAL MINERALS AND STRUCTURAL MATERIALS AS A PERCENT OF TOTAL

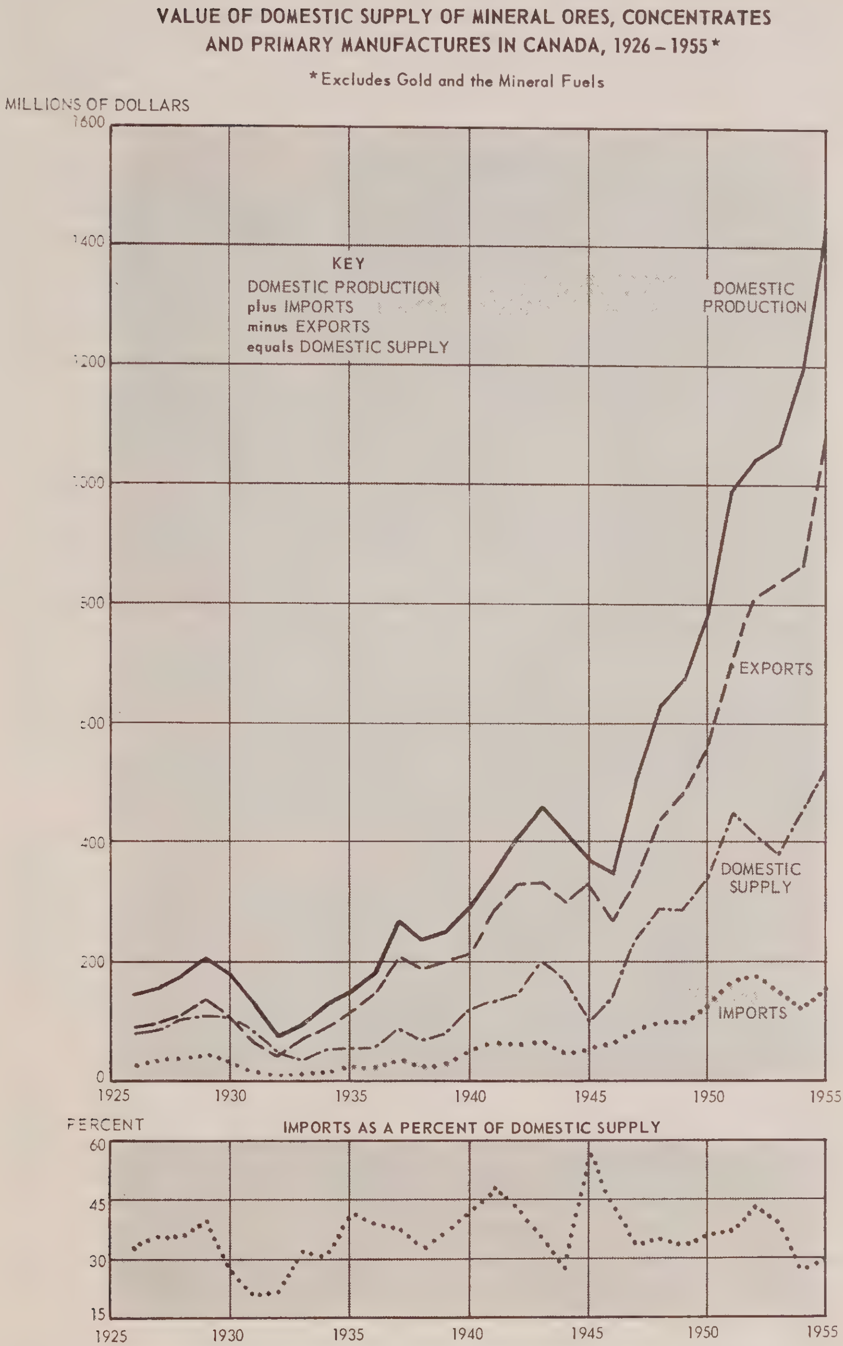


VALUE OF IMPORTS OF ORES, CONCENTRATES AND PRIMARY MANUFACTURES INTO CANADA, 1926 – 1955 *



ORES, CONCENTRATES AND PRIMARY MANUFACTURES AS A PERCENT OF TOTAL




VALUE OF DOMESTIC SUPPLY OF MINERAL ORES, CONCENTRATES
AND PRIMARY MANUFACTURES IN CANADA, 1926 – 1955*
*Excludes Gold and the Mineral Fuels
MILLIONS OF DOLLARS
KEY
DOMESTIC PRODUCTION
plus IMPORTS
minus EXPORTS
equals DOMESTIC SUPPLY
DOMESTIC PRODUCTION
EXPORTS
DOMESTIC SUPPLY
IMPORTS
1925
1930
1935
1940
1945
1950
1955
PERCENT
IMPORTS AS A PERCENT OF DOMESTIC SUPPLY
60
45
30
15

mately fourfold. Canadian consumption in the early 1950's was approximately two and one-half times that reported a quarter century earlier. Imports needed to meet the expanding requirements of the aluminum, primary iron and steel, equipment, building and construction industries in this country have approximately doubled during the 30-year period under review.

An even more concrete measure of growth is afforded by the D.B.S. series on employment. The chart entitled, Employment in Mining, Canada, 1926-55, shows the numbers of jobs provided by the nation's various mines and primary processing plants, rising from 70,000 in the late 1920's to approximately 100,000 in recent years. As the employment opportunities afforded by the energy industries, coal, oil and natural gas, actually declined, the numbers of workers engaged in the mining and other activities covered by this study exhibited a more than proportionate increase. They rose by about 80% from around 40,000 jobs in the late 1940's to 73,000 in 1955.

In the meantime, the working week of the average employee has declined. Around 52 hours in the late 1920's, it has subsequently fallen to 43 hours a week, or about five-sixths of that reported 25 years ago. Multiplying the average annual employment and weekly hour figures together, we find that the number of man-hours worked by Canadians employed in this group of industries has risen by approximately 50%.

Compared to real output, this is a remarkable achievement. A 50% increase in labour input has yielded, over the years, a 250% increase in production. Output per man-hour, in other words, has gone up nearly two and one-half times. Calculated as a yearly average, this works out to the equivalent of a 3.5% annual rate of growth in labour productivity.

Hourly earnings have risen correspondingly. Expressed in current money values, they increased from around 60¢ an hour in 1926 to $1.50 an hour in 1955. Meanwhile, salaries and wages, as a sum total, rose to about four times the level reported in the late 1920's. Output, as has been noted, went up more—namely, around sevenfold. Whereas salaries and wages constituted more than 30% of the industries' gross value of production in the late 1920's, the average for the years 1951-55 was closer to 20%.[1] Labour's role (and hence labour's share) in the industries' total activity is apparently on the wane.

Mechanization has been a contributing factor. The amount of capital invested per employee has increased. A greater amount of labour, in other words, is being brought into each new mining area in the form of building materials, machinery and process supplies. Being more capital-intensive, the local impact of new developments is less than it was formerly. Modern methods of exploration, equipment and organization are gradually changing all that.

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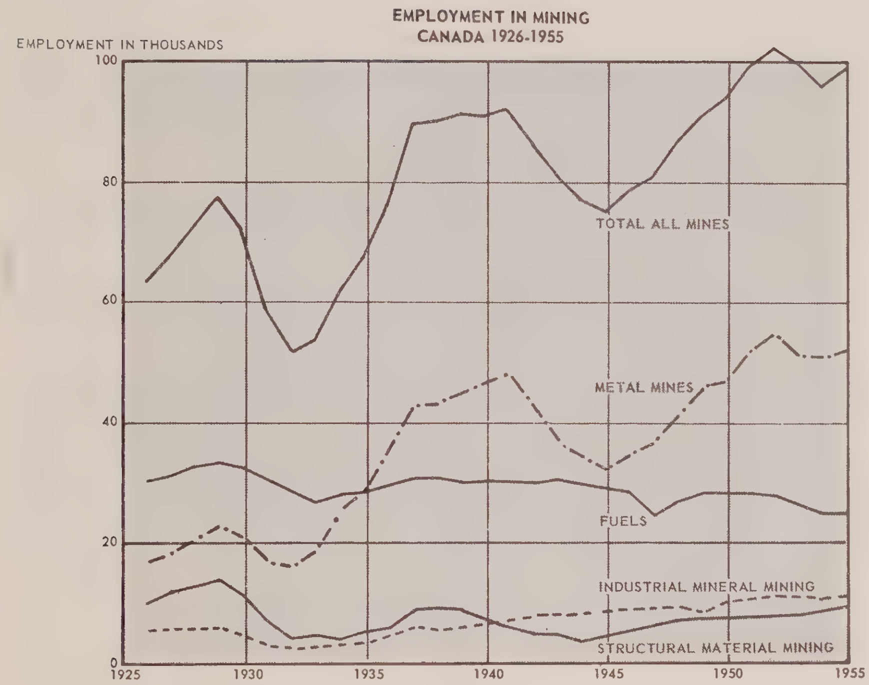
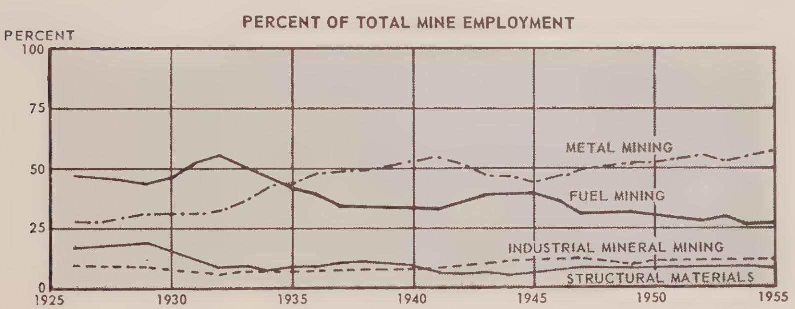
[1]Salaries and wages as a percentage of gross value of mine production was 35% in the years 1926-30, 30% in 1946-50 and 32% in 1951-55. The corresponding figures for smelting and refining are 1926-30, 21%; 1946-50, 9% and 1951-55, 10%. See also Statistical Appendix page 385.


EMPLOYMENT IN MINING
CANADA 1926-1955
EMPLOYMENT IN THOUSANDS
100
80
60
40
20
0
1925
1930
1935
1940
1945
1950
1955
TOTAL ALL MINES
METAL MINES
FUELS
INDUSTRIAL MINERAL MINING
STRUCTURAL MATERIAL MINING


PERCENT OF TOTAL MINE EMPLOYMENT
PERCENT
100
75
50
25
0
1925
1930
1935
1940
1945
1950
1955
METAL MINING
FUEL MINING
INDUSTRIAL MINERAL MINING
STRUCTURAL MATERIALS

In summary, it can be said that:

(i) the mining industry constitutes one of the most (if not the most) rapidly growing sectors of the Canadian economy;

(ii) over the past 30 years, it has become more, rather than less, export oriented;

(iii) the extent to which Canadian minerals have been processed prior to export increased from the late 1920's until the end of World War II. Since 1945, the degree of processing of Canadian produced minerals, prior to their sale in the United States and elsewhere, has declined;

(iv) there has been a remarkable improvement in the productivity of Canadian labour employed in Canadian mines, smelters and refineries. Since 1926, output per man-hour has risen at an average rate of around 3.5% a year. This is considerably above the national average of approximately 2%; and

(v) as the Canadian mining industry has become more capital-intensive, its local impact (in terms of employment, or salaries and wages paid to on-site labour) has tended to lag behind such measures of output as gross value of production and total value of sales.

5

LONG-TERM MARKET AND PRODUCTION TRENDS

A. General

(a) *Forecasting Mineral Futures*

Market analysts, concerned about future sales prospects, usually attempt to look a decade ahead. Most mining companies, concerned about future demand, also confine their attention to the next five to ten years. Recently, they have been fortified by better factual information as to physical availabilities, costs of production and changing patterns of consumption. Yet forecasters, armed with the latest estimating techniques, are also having to contend with:

(i) the increasing tempo of technological change; and

(ii) the growing complexity of the market for most mineral products.

The 25-year projections which appear in this report must, therefore, be regarded more as indicators of present rates of change than as definitive estimates of the market for each individual mineral in 1980.

Long-run consumption trends characteristically exhibit greater continuity than those pertaining to mine output. Commercial inventory building programmes, stockpiling for defence and consumption from accumulated reserves, have often caused production to fluctuate more than demand. Our procedure has, therefore, been to begin each commodity study with a review of consumption, first on a global and then on a major regional or continental scale.

The length of time during which a particular mineral has been in commercial usage has a good deal to do with the slope of its demand curve. Starting slowly at first, consumption of most mineral products soon begins to rise rapidly. For a decade or two, it outpaces that of most other raw materials. Then there comes a time (and this may be many years after it began to be

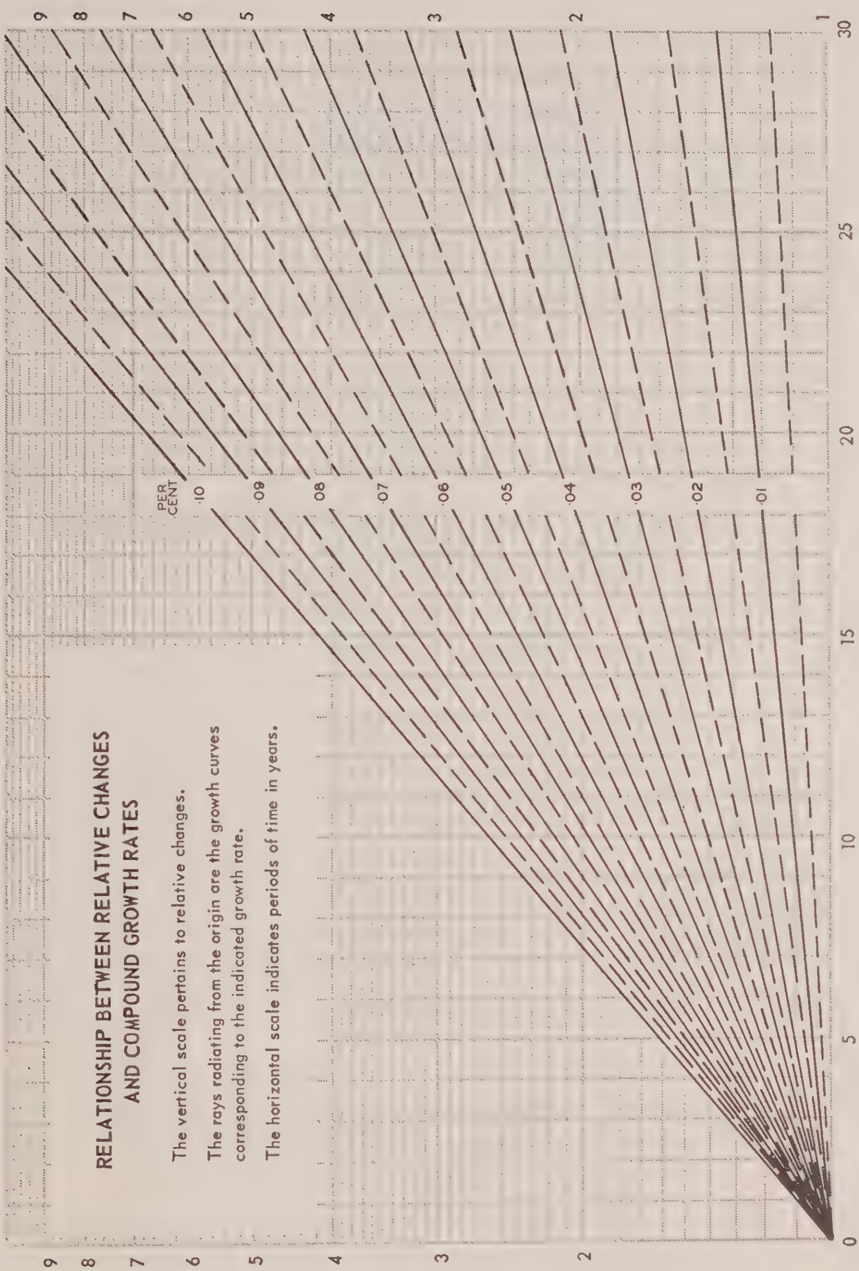
used in quantity) when global requirements begin to level off. Finally, consumption may actually decline; relative, that is, to most other mineral products. By an examination of the changing characteristics of demand with time, it has sometimes been possible to discover whether the market behaviour of the mineral in question may be typical of an early, intermediate or mature stage of demand growth.

In most cases, consumption is seen as tracing out an upward trending curve similar to that expressed by a compound rate of interest. Past average rates of growth have, in this fashion, been applied to 1955 data, with a view to determining the likely level of demand 10 and 25 years hence. Though subsequently modified as a result of information as to individual use and regional requirements, the resultant consumption curve (when plotted on ordinary graph paper) tends to bend upward with the passage of time. Arithmetic relationships corresponding to given annual percentage rates of growth are quantified in the chart entitled Relationship between Relative Changes and Compound Growth Rates.

Lending support to this approach is the fact that the demand for minerals is determined by two underlying influences, both changing in geometrical rather than arithmetical fashion. Population is rising along a compound growth rate line. Man-hour productivity also accelerates with the passage of time. Total economic output, being a composite of the two, therefore tends to draw mineral consumption along with it at a comparatively constant, rather than diminishing, annual rate of change. Such deviations as may result from unusual developments on the demand side are merely assumed to give an upward or downward bias to what people still regard as an inherently optimistic projection of future market requirements.

While over-all demand forecasts are useful for orientation purposes, it is often possible to go behind these highly generalized statistics and identify long-term trends by major end-use. Closer reasoning, linking demand in particular applications with the outlook forecast for various mineral using industries (as reported in the Commission's other published studies) provides additional insight into some of the complex technological factors influencing demand. Also, by following this approach, it has been possible to avoid contradictory assumptions as to use which might otherwise have been made in circumstances where minerals can be used one in lieu of the other.

Price is one of the most useful indicators of economic change. Its movement relative to that of other goods and services is a reflection both of mineral availability and demand. For this reason, historical series were prepared, the current market price for each metal or non-metal being divided by the wholesale series applicable to all commodities.


RELATIONSHIP BETWEEN RELATIVE CHANGES
AND COMPOUND GROWTH RATES
The vertical scale pertains to relative changes.
The rays radiating from the origin are the growth curves
corresponding to the indicated growth rate.
The horizontal scale indicates periods of time in years.
PER CENT
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
5
10
15
20
25
30
1
2
3
4
5
6
7
8
9

In circumstances where the real price has moved consistently one way, this situation, barring quantitive information to the contrary, has been assumed to continue through to 1980. Thus, in the case of nickel, aluminum, magnesium, titanium and potash, further reductions in price relative to the general price level were assumed to give these minerals a further competitive advantage over the next quarter century. Iron ore is typical of a mineral whose market price has been (and may continue to be) comparatively stable over the long run. Copper and asbestos prices, on the other hand, have shown a definite long-run tendency to rise. In each case, assumptions re future price movements have been determined after an examination of the historical real and current price series such as those set out in the charts entitled Price Trends, Current and Deflated: U.S. Annual Averages: 1900-55.

Regional availabilities have been studied with a view to determining the share of the North American and overseas markets which Canadian producers might reasonably expect to obtain over the next quarter century. Here, reliance was placed upon confidential memoranda and reports published by Canadian federal, provincial, United States and other specialized government agencies. Forecasts appearing in the technical press and attributed to well-known market analysts have also been quoted in this connection. Interviews with and comments received from a number of executives with mining companies operating in Canada have also helped to shape the various commodity forecasts appearing in this chapter.

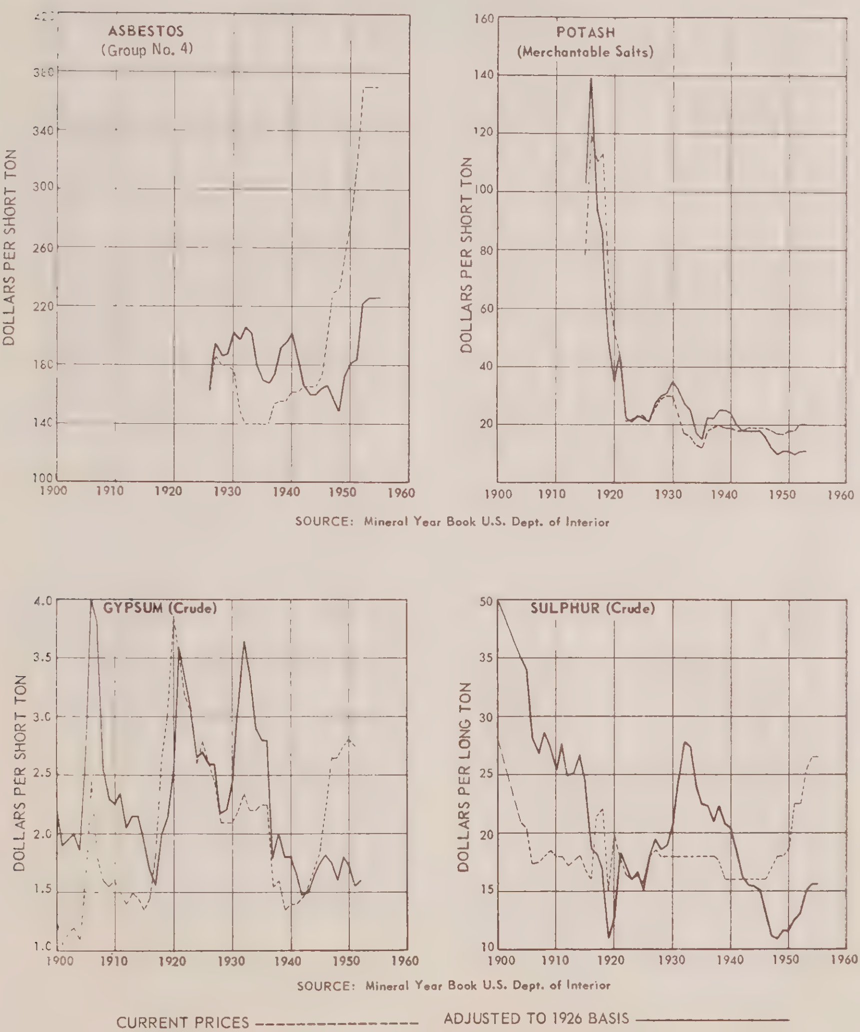
Consideration was given to such lasting influences as defence procurement, government stockpiling, existing tariff policies and the future purchasing power of countries whose ability to earn hard currency has caused them to curtail their purchases of minerals from Canada in recent years. Influences of a discriminatory character which militate against a maximization of Canadian trade have not, however, loomed large in our calculations. Instead, the view has been taken that economic considerations of a more fundamental character will have a great deal more to do with the world supply-demand position as it emerges in 1980. In general, it should be remarked that:

(i) the following forecasts of consumption usually result in higher estimates of demand (and hence will be regarded as more optimistic) than others of a similar character that have been published in recent years;

(ii) reflecting a comparatively healthy long-run supply position, real prices have usually been assumed to remain relatively constant or tend to decline relative to that of other goods and services over the next 25 years; and that

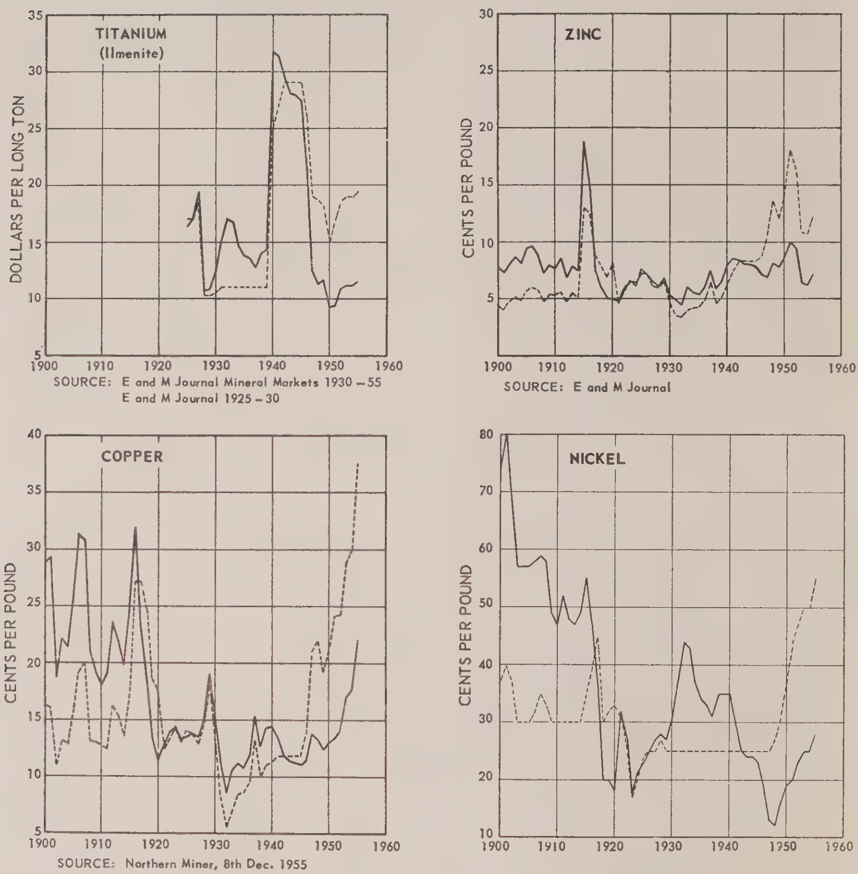
PRICE TRENDS, CURRENT AND DEFLATED

U.S. ANNUAL AVERAGES 1900 – 1955



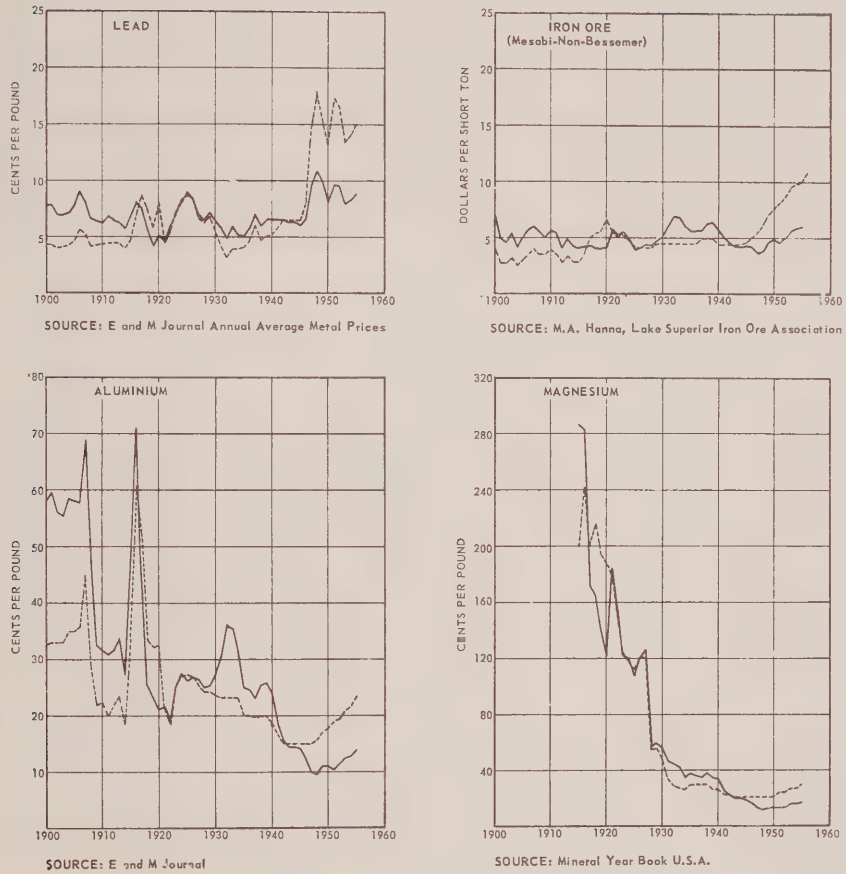
PRICE TRENDS, CURRENT AND DEFLATED

U.S. ANNUAL AVERAGES 1900 – 1955



CURRENT PRICES ---------------- ADJUSTED TO 1926 BASIS ————————

PRICE TRENDS, CURRENT AND DEFLATED
U.S. ANNUAL AVERAGES 1900–1955



CURRENT PRICES ------ ADJUSTED TO 1926 BASIS ————

(iii) while Canada's share of the world market for certain minerals may fall relative to world production, the outlook, in most cases, is for a considerable increase in Canadian mine output, domestic consumption and Canadian exports of ores, concentrates and other primary mineral products.

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B. Iron Ore

(a) *General Introduction*

Industry and steel, to many, are synonymous. Well might they be. Both are dependent on iron, and both are therefore dependent on iron ore. Iron ore then is the key. No other material, unless it be coal or oil, moves in such vast quantities. No other material in its processed forms serves such a vast area of uses. Because of this, steel has come to be regarded as one of the mainstays of modern economic life. Hence the discovery and recent development of extensive iron ore resources in this country have been hailed as important factors influencing Canada's economic growth.

Iron is a common metal. Combined chemically with other elements like oxygen and sulphur, it constitutes nearly 5% of the earth's crust. But iron ore in commercially attractive grades and quantities is something else again. It is not one thing, but many. It may have a content as high as two-thirds iron, or it may be so laden with impurities or so difficult to process as to be verging on plain waste rock.[1]

Some ores, in other words, are highly desirable, others less so; still others can be used only as a last resort. The highest grades usually command premium prices since they can be used as a sweetener in making up blast furnace charges. The medium-grade ores, fetching more moderate prices, usually supply most of the steel industry's requirements. The lower-grade

[1]The lower-grade ores frequently contain large proportions of such gangue materials as clay and silica. Appreciable quantities of sulphur, phosphorus, arsenic, titanium and copper may also render its processing more difficult or render less acceptable the iron made from it.

materials, though they are much more abundant in nature, must receive prior treatment before they can be processed economically by the producers of primary iron and steel. As long as the richer material was plentiful, the lower-grade deposits were mined only for blending purposes if, indeed, they were mined at all.

Now, with the rapid depletion of a number of North America's larger and better-known high-grade mines, the steel industry's views on quality are changing. Greater recourse, of necessity, is having to be made to lower-grade material. Processes are being devised for the upgrading or beneficiation of the leaner and more refractory ores. Helping to offset the additional costs of treatment is the fact that the prepared product has a higher iron content and can be produced in a form more suitable for charging to the furnaces. However, in circumstances where the over-all costs of mining, preliminary treatment and processing into steel are tending to rise, the obvious alternative is to go farther underground or to look farther afield in search of alternative sources of supply.[2]

Meanwhile, the steel industry's views as to what constitutes an ore body are also changing. Owing to the large tonnages involved, the problem of supplying iron ore is largely one of materials handling. Improvements at the mine and in overland transportation and developments which lead to further economies in water-borne transportation are helping to offset the additional expenses involved in ore preparation. Larger and more highly specialized ore-carrying ships, complete with self-loading and unloading equipment, are being built. Conveyor and other systems are being introduced on high density overland routes. Beneficiation, by eliminating most of the waste rock and other extraneous material at the mine is also helping to minimize transportation costs. These developments, together with the fact that productivity gains promise to be higher in the open-pit type of operation, is encouraging many steel producers to look farther afield in search of resources which can be mined easily, treated with a minimum of expense and transported easily to existing mills.

Demand will continue to increase. Of this most executives in the steel industry are now convinced. Each new addition to smelting and fabricating capacities requires, in parallel, the establishment of additional iron ore reserves. Cost considerations (including the capital investment per ton of ore produced) put an upper limit on the amount of ore that can economically be won from underground mines or by processing the more refractory

[2]Owing to the high cost of new blast furnace construction the present trend is to use ores containing the highest possible iron content. The standard grade of direct-shipping ore over the years has been 51.5% iron and a maximum of 10% silica. More recently it has been proven that by using a charge of 60% to 65% iron content in pelletized, sintered, briquetted or nodulized form, production from existing blast furnaces could be increased by as much as 20%. These findings have already had a considerable bearing on the opening up of deposits of ore which were relatively low in grade but which could be readily concentrated to beyond 60% iron. Besides possessing a number of deposits of relatively high-grade direct-shipping ore, Canada also has extensive deposits of lower-grade material which respond readily to beneficiation.

iron bearing materials like taconite. New and more readily expandable sources have to be found. With this need in mind, North American producers are looking beyond the confines of the United States to countries like Venezuela, Chile, Peru and Liberia for supplementary sources of supply. Canada, because of its stable political climate, favourable mineral taxation policies and the geographical proximity of iron ore deposits to United States steel plants, has also been attracting a good deal of attention.[3]

(b) *Background and Industry*

The presence of iron in Canada has been known for a long time—one might even say for centuries. Bog iron was first mined in Three Rivers, Quebec, in 1732. The smelting of local ores using charcoal was also practised intermittently in the Maritime Provinces and Southern Ontario for some 150 years. Numerous other ore bodies, the majority low in grade and with limited lives, were worked sporadically in the 1880's and 1890's. Even at that, Canada's total output up until 1924, when production ceased, amounted to no more than six million tons, despite the fact that several of the larger iron ore deposits being worked today were known, or their existence at least suspected, by the earlier geologists and prospectors.

Yet, what had been previously turned up was of little commercial interest after high-grade, direct-shipping ore had been found in what were then astonishingly high tonnages. Not only were these new deposits surprisingly uniform in character but they were also easier to mine, easy to haul to the mills and easy to manufacture into a good quality of pig iron. Unfortunately for Canada, these deposits were in the United States, lying generally south and west of Lake Superior. Interest in this country's iron ore potential waned. To most people it looked as if Canada would never again become self-sufficient so far as the production of iron ore was concerned. In Minnesota, close to the southeastern fringe of the Canadian Shield, lies the famous Mesabi Range. Though much of its better-grade and more readily mined material has now been extracted it is still regarded as one of the largest and most varied iron formations on earth. It stretches like a great carpet a hundred miles long and several miles in width across the countryside. It is comprised of not only one grade of iron ore, but many, with deposits of hematite often outcropping at the surface and surrounded and underlaid by vastly greater quantities of taconite—varying mixtures of commercially desirable ore and waste rock which are also characteristic of most of the other Lake Superior and some of the Canadian iron ranges. At best the latter is one-third iron and, yet, sprinkled here and

[3]U.N. data indicate the approximate metal content of ores and concentrates shipped from the mines. For Canada the figure given for the year 1951 was 55%, that for Venezuela was 65% as compared with 60% for the U.S.S.R. and Sweden, 50% for the U.S., 35% for France and 30% for the U.K., Western Germany and Luxembourg.

there are pockets of higher-grade ores themselves, amounting to hundreds of millions of tons of immediately marketable material.[4]

After these important iron mining areas were opened up in the 1890's, few steel companies, either in Canada or the United States, were even remotely interested in searching for alternative sources of supply. Here, only a few miles from cheap water transportation, lay what seemed at the time to be almost inexhaustible tonnages of direct-shipping ore. Very little effort was needed to move it by water into the industrial heartland of the continent. As a result, the steel mills around South Chicago, Pittsburgh, Cleveland, Hamilton and Sault Ste. Marie turned unhesitantly to the Lake Superior iron ranges as their principal source of supply.

Sixty years and two world wars later, these views are changing. Though a few companies are well protected because of extensive holdings within their own control,[5] others have less than ten years of easily won direct-shipping ore in sight. They are the ones who first began to look elsewhere. Because of similar geological conditions and the possibility of transporting Canadian ore to the mills over internal lines of supply, interest in this country's better known possibilities began to revive during World War II.

Their investigations, though far from complete, have been rewarding. Various iron-bearing occurrences, large and small, scattered across the Canadian Shield from the southeastern tip of Manitoba all the way to the Atlantic Coast of Labrador, have been revealed. (See map entitled Iron Deposits and Blast Furnaces in Canada, 1956.) Formations like those which have been so prolific in Minnesota occur again in Western Ontario. Iron formations have been outlined near Sault Ste. Marie, north of Sudbury and on the Belcher and Nastapoka Islands in Hudson's Bay. Still further eastward, iron-bearing formation is now known to constitute a great belt commencing in central Quebec and continuing northward along the Quebec-Newfoundland border to Ungava Bay.

Direct-shipping ore has been found under Steep Rock Lake, just west of Port Arthur on the Canadian side of the International Boundary. At the eastern end of the country, along the Labrador Trough, the extent of high-grade deposits can be measured not in yards, but in miles. It is the Mesabi all over again, but with this difference: the deposits, instead of sloping off gradually to greater depths appear to be relatively shallow, often outcropping at the surface. This means that they too can be mined efficiently using modern equipment and open-pit mining techniques.

[4]There remains approximately one billion tons of material now reported as open-pit direct-shipping ore. At present rates of consumption, these U.S. resources would be used up in less than 15 years' time. The taconites, which can be concentrated by fine grinding and magnetic means amount to about two billion tons at the surface and many times this figure underground. The non-magnetic (and hence more difficult to recover) taconites are known to be available in even greater quantities.

[5]e.g. U.S. Steel alone controls over 75% of the remaining open-pit direct-shipping ores proven up in the Mesabi Range.

IRON DEPOSITS AND BLAST FURNACES IN CANADA, 1956

IRON DEPOSITS

1 WABANA (hematite)
2 NICTAUX-TORBROOK (magnetite and hematite)
3 BATHURST (magnetite, hematite, sulphides)
4 NATASHQUAN (magnetic beach sands)
5 ALLARD LAKE (ilmenite-hematite)
6 MARYBELLE LAKE (titaniferous magnetite)
7 LABRADOR-NEW QUEBEC (goethite, hematite, limonite)
8 MATONIPI LAKE (iron formation)
9 ALBANEL LAKE (iron formation)
10 BRISTOL (magnetite)
11 NORANDA (pyrite)
12 NASTAPOKA ISLANDS (iron formation)
13 BELCHER ISLANDS (iron formation)
14 CALABOGIE (magnetite)
15 MARMORA (magnetite)
ALLAN MILLS (magnetite)
CAMPBELLFORD (magnetite)
16 MOOSE MOUNTAIN AREA (magnetite)
17 SUDBURY (pyrrhotite)
18 BOSTON IRON RANGE (magnetite)
19 KAPUSKASING (magnetite)
20 GOULAIS (magnetite)
21 MICHIPICOTEN AREA (siderite)
22 NAKINA (magnetite)
23 GUNFLINT (iron formation)
24 ATIKOKAN IRON RANGE (magnetite)
25 STEEP ROCK LAKE AREA (goethite)
26 MINE CENTRE (titaniferous magnetite)
27 BRUCE LAKE (magnetite)
28 BURMIS (titaniferous magnetite)
29 PEACE RIVER AREA (siderite)
30 KIMBERLEY (iron tailings)
31 KITCHENER (hematite)
32 TEXADA ISLAND (magnetite)
33 QUINSAM LAKE (magnetite)
34 ZEBALLOS (magnetite)
35 QUATSINO (magnetite)

LEGEND

IRON ORE PRODUCING AREAS .... ◎
KNOWN PRINCIPAL IRON OCCURENCES . ○
IRON BLAST FURNACES .... ●
QUEBEC-LABRADOR IRON BELT ....

BLAST FURNACES

A Sydney, Nova Scotia
Dominion Iron and Steel Co., Ltd.

B Port Colborne, Ontario
Canadian Furnace Co., Ltd.

C Hamilton, Ontario
The Steel Company of Canada Ltd.
Dominion Foundries and Steel Ltd.

D Sault Ste. Marie, Ontario
Algoma Steel Corporation

MAIN GEOLOGICAL REGIONS

CANADIAN SHIELD .... ①
INTERIOR PLAINS, ST. LAWRENCE, HUDSON BAY AND ARCTIC LOWLANDS .... ②
APPALACHIAN .... ③
CORDILLERAN .... ④
INNUITIAN .... ⑤

One should not conclude from this that no other significant iron ore deposits exist. Extensive deposits, unique in character, exist at Wabana off the coast of Bell Island in Newfoundland. They alone constitute one of the world's largest reserves. Ores of the carbonate type are being worked in the Michipicoten area north of Sault Ste. Marie. Others of a magnetite-skarn type occur in commercial quantities in southeastern Ontario, the adjoining part of Quebec and on the Pacific coast of British Columbia. Where they can be mined by open-pit methods or concentrated with a minimum of processing, they are also forming the basis of mining operations.

In addition to the properties already in production or slated for early production, there are many areas, particularly in Ontario and Quebec, that warrant exploration by diamond drilling, geological and geophysical examination. Favourable iron-bearing formations are known to extend in an almost continuous arc from the most northerly tip of the west coast of Ungava Bay southward along the Quebec-Labrador boundary to the Wabush Lake area and then westward to the Mistassini area of Quebec.

In Ontario, there are also a number of areas containing iron-bearing deposits of possible commercial importance. The areas of interest are widely scattered. Beginning in the southeast corner of the province, they run north to Kapuskasing, and thence westward to the Manitoba boundary. On the coast of British Columbia, on Vancouver Island and the offshore islands many occurrences of beneficiating-grade magnetite are on record. In general, these latter deposits all have limited reserves in comparison with the huge potential of those in Ontario and Quebec but detailed examination by magnetic means followed by diamond drilling could prove up further deposits of economic value.

It is not possible to assess arithmetically the iron ore reserves of Canada, but those that have been measured, indicated and inferred are so great that they are more than ample for domestic and export requirements far into the future. From the relatively little detailed exploration that has taken place on known iron ore deposits, Canada has proven reserves of close to one billion tons of direct-shipping ore in the Quebec-Labrador iron belt and Steep Rock Lake areas. Indicated reserves of hematite ore at Wabana are measured in several billions of tons. The enormous reserves of concentrating ore, ranging from 30% to 42% iron, in known deposits and ranges of Quebec-Labrador and Ontario are far greater in extent. They amount to many billions of tons of beneficiating ore.

The first Canadian iron range to divert popular attention away from the main American iron ranges was Steep Rock. Rumours had persisted for years that iron was to be found at the bottom of Steep Rock Lake. Early geological surveys supported this contention.[6] Yet it was not until 40 years later that

[6]As early as 1897, the Geological Survey of Canada published a map of the Steep Rock area. Included was a footnote to the effect that "iron bearing horizon with hematite of good quality appears to be covered by the waters of this lake".

the first commercial ore bodies were definitely located. Another five years were needed to assemble the necessary evidence, to overcome the doubting Thomases, and to raise the money for Steep Rock's initial development. Had it not been for the impetus of World War II, a much longer period might well have been required. As it was, Steep Rock only began to be taken seriously in 1939. Yet shipments of ore, which commenced in 1945, are now mounting rapidly. Last year they amounted to about 3.5 million long tons. By the early 1960's, Steep Rock and its environs may have an annual capacity in excess of eight million tons—more than double Canada's total production in the year 1950.

The Steep Rock discoveries, despite the publicity they have received, are by no means the only Canadian workings adjoining the upper Great Lakes. Nor were they the first to come into production. The modern Canadian iron ore industry had its beginnings in 1939 when Algoma Ore Properties Ltd. brought its Helen mine, in the Michipicoten area of Ontario, back into production after a closure of some 20 years.[7]

Strange to say, this entrance was not based on high-grade direct-shipping ores but on low-grade beneficiating materials. The ore in this area, siderite, contains small quantities of the desirable alloying element, manganese. Sintering at the mine does two things. It raises the iron content of the ore and, also by changing its physical characteristics, makes it a more desirable blast furnace feed. It is for this reason, as well as the ore's self-fluxing qualities and its manganese content that about four-fifths of the output of the Michipicoten mines and sintering plant is being exported to the United States through lower lake ports. The remaining one-fifth, which is not exported, is transported by rail to the parent company's steel plant at Sault Ste. Marie.

Algoma Ore Properties followed its Helen mine, when the economic depth of open-pit operations was reached in 1945, with the Victoria open-pit mine. The Victoria mine, in turn, was followed by the Helen underground mine in 1950 and the Victoria underground mine in 1954. Currently a new open-pit, the Sir James mine, is being developed for production. The rated capacity of the company's plant at Jamestown is being increased to 2.0 million long tons of sinter per year.

The Sudbury area, long famous as the source of much of the world's nickel, recently became a producer of iron ore as well. In this case it is a by-product. As much as one million tons a year may soon come from the processing of nickel-bearing pyrrhotite. A recently completed plant at Copper Cliff treats materials previously considered too low in grade to be economically mined and processed. This process has made possible the extraction of ores which have hitherto been considered sub-marginal. The iron oxide pellets produced are very high in iron and exceptionally low in

[7]The old Helen geothite mine was first opened in 1900 and finally closed in 1918 due to the exhaustion of its ore. Another adjoining mine, the Magpie, operated intermittently from 1911 to 1921 inclusive.

silica. For these reasons, and because of their desirable physical properties, the pellets command a premium price as open hearth furnace feed and thereby help to make North American steel producers less dependent upon overseas sources of supply.

There is little more than a family resemblance between the latest mining operation in eastern Ontario and the new mines in Quebec-Labrador. Both involve open-pit mining. They employ the latest and largest types of rock moving equipment. Both have required the establishment of new rail and water connections on the St. Lawrence River system and both have resulted in the production of material which is higher in grade than that normally charged to most blast furnaces on this continent.

There the resemblance ends. The differences are largely those of scale, though on-site processing comes into it as well. Marmora, though a sizable development on its own, is a pygmy compared to the giant undertakings around Knob Lake. One has, as its immediate target, an annual output of around half a million tons of pelletized concentrates. The other envisages a yearly level of output in excess of 20 million tons. Marmora, being closer to its markets,[8] renders economic the on-site processing of its lower-grade magnetite. The Quebec-Labrador venture, on the other hand, would never have been economic had it not been for vast amounts of direct-shipping ores.

But one cannot conclude that beneficiation will be confined to the deposits found within easy reach of the Great Lakes. Where concentration can be effected at a minimum of cost it may pay to process 30% to 40% iron bearing material, thereby maximizing the amount of iron which it contains and reducing over-all costs of shipment.

The Quebec Cartier Mining Company, a subsidiary of United States Steel Corporation, announced recently that it will spend an estimated $200 million to bring its iron ore holdings, about 300 miles northeast of Quebec City, into production. The company has proven up by diamond drilling large reserves of iron ore averaging about 31% iron, in the Mount Wright and Mount Reed areas some 150 miles north of Shelter Bay on the St. Lawrence River. Initial production is expected in 1961 from a concentrating plant having a capacity of 10 million tons of high-grade iron concentrates a year. Eventual production from the company's mines in the area could reach several times this figure.

A number of other companies prominent in North American iron ore, iron and steel industries are engaged in large-scale exploration programmes both to the southwest part of the Quebec-Labrador iron belt and west of Ungava Bay. Some of these will undoubtedly lead to development and production within the next few years.

[8]Sizable tonnages of iron ore pellets produced by the Marmora mine are being shipped to the Bethlehem Steel Corporation's plant at Lackawana near Buffalo, N.Y., via the company's ore dock at Picton on the Bay of Quinte, Ontario.

The Atlantic Region already has a large stake in developing overseas markets for iron ore. The Wabana Mines in Newfoundland have pioneered this trade. They have been producing continuously since 1895. Though their principal customer has for years been the parent Dominion Steel and Coal Corporation just across the Cabot Straits in Nova Scotia, some two million tons a year are now being shipped across the Atlantic to steel mills in Great Britain and West Germany.

These mines are submarine, lying off the coast of Bell Island in Conception Bay. Hence, surface transportation costs can be pared to a minimum. The Wabana reserves are also better than 50% iron. Only because they contain appreciable amounts of phosphorous and silica have they failed to come into general use on this continent. Because they resemble more those in use in Western Europe, sales from these Canadian mines will probably continue, in large measure, to be made overseas.

Our story, so far, has been confined to developments in and around the Canadian Shield. It has been told as if all of Canada's operating mines were in central and eastern Canada. But one must also take into account developments on the west coast. Several new mines have been opened up and markets developed, the servicing of which could also become a permanent feature of Canada's iron ore trade. In the late 1930's, and again since 1951, shipments of iron ore have been made from British Columbia to Japan. In 1955, for example, 500,000 tons were produced from two areas—Texada Island, a source almost within sight of Vancouver, and Quinsam Lake, near Campbell River on the east coast of Vancouver Island. Though production from this and other west coast sources will continue to move in some volume to the Orient, the day may be approaching when local markets in this country will also demand substantial amounts of iron ore from nearby sources in Western Canada.

Quantitatively, the record of production in recent years has been impressive. Canada has moved from a country whose output of iron ore was of little consequence to a position among the first four world producers today.[9] Even including the output of the Newfoundland mines, production failed to reach the two million tons a year level until World War II. In 1950 it was still in the order of three million tons. By 1955, however, with increased shipments being made from Quebec-Labrador and other Canadian sources, domestic production rose to 14.5 million long tons. Meanwhile, exports exceeded imports for the first time in 1953. Though the great bulk of the Canadian produced ore is now being consumed outside the country, approximately 1.5 million tons are being processed in Canadian blast furnaces at present.

[9]The Canadian share of world production amounted to 4.5% in 1955. In that year Canada competed with Sweden, the United Kingdom and Germany for fourth place. In 1956 Canada was definitely the world's fourth largest producer following the U.S., the U.S.S.R. and France in that order.

Table 5

PRODUCTION, TRADE AND CONSUMPTION OF IRON ORE IN CANADA[a]

(average in millions of long tons per year)

	Mine shipments	Imports	Exports	Domestic consumption
1920-25	0.7	0.7	0.4	1.1
1925-30	1.2	1.1	0.7	1.6
1930-35	0.5	0.4	0.4	0.6
1935-40	1.3	0.9	0.7	1.5
1940-45	1.4	2.1	0.5	2.9
1945-50	2.7	2.5	1.8	3.4
1950	3.2	2.8	2.0	4.0
1951	4.2	3.4	2.9	4.7
1952	4.7	3.8	3.4	5.2
1953	5.8	3.7	4.3	5.3
1954	6.6	2.7	4.8	4.5
1955	14.5	4.0	13.0	5.5

a Including Newfoundland.

(c) The Market Outlook

The output of Canada's iron ore mines is rising rapidly. During the last 12 months—that is, during 1956—it increased by approximately 50% to better than 20 million long tons a year. Plans projected through to the mid-1960's envisage production exceeding 45 million tons. Estimates of capacity in the mid-1960's run as high as 60 million long tons annually. Thus, even if the North American steel industry were operating at between 70% and 80% of capacity, the Canadian iron ore industry may be turning out something like 50 million tons a year a decade from now.

In attempting to look even further ahead to 1980, greater attention must be paid to long-term trends in iron ore requirements. Over the past half century, world consumption has been mounting at an average rate of between 1.5% and 2% a year.[10] This differs little from the North American average from the mid-1920's through to 1955. Were demand to continue upward at this rate, it would increase by approximately one-third during the 15 years from 1965 to 1980. Assuming that the markets available to Canadian ore grew at a comparable rate, production in this country might range anywhere between 60 million and 80 million long tons a quarter of a century from now.

These are large assumptions. Yet they could turn out to be on the conservative side. The demand for steel may grow even more rapidly than that envisaged here. Steel scrap may continue to be in short supply and therefore the amount of new iron required by the steel mills may rise at a rate closer to 2% per annum. Technological developments in respect to furnace opera-

[10]A sustained annual rate of increase of 1.75% results in a 50% increase in requirements over a 25-year period.

tion and design (e.g., the greater use of oxygen vessels) may have a similar effect. On the other hand, some of the countries of Western Europe, though they would prefer to buy Canadian ore for reasons of quality and ready deliverability, may continue to limit their purchases for exchange reasons. Canadian ore may also encounter increasing competition from South American and African sources in its markets on both sides of the Atlantic. These various factors have been taken into account in preparing the following estimates of regional requirements.

The United States is, and undoubtedly will continue to be, the largest single market for Canadian ore. United States consumption is at present of the order of 140 million long tons a year. Over the next 25 years, it may rise by better than 50% to around 220 million tons of ore annually. Meanwhile, the output of the American mines may decline slowly to a 100 million ton a year level. The United States deficit in 1980 may therefore be in the order of 120 million tons a year. This amount, on the average, will have to be imported each year in the late 1970's and early 1980's. Were Canada to share proportionately with other foreign sources of supply, Canadian exports to the United States might therefore be in the vicinity of 60 million long tons annually 25 years from now.

A similar view is expressed in a recent forecast prepared by R. W. Holliday of the United States Bureau of Mines (see "Iron", a chapter from *Mineral Facts and Problems,* Bulletin 556, Bureau of Mines, United States Department of the Interior, 1956). This United States government source reads in part:

> "The Lake Superior region will continue to be the principal source (of U.S. iron ore supply), with an estimated annual output of 100 million tons through 1960; however, during that period the United States will have lost one of its important strategic assets—the ability to expand and contract production in quick response to demand. Volume production from new sources in Canada and Venezuela will relieve this pressure. Nevertheless, demand is expected to remain strong enough to maintain domestic production at a high level, and the longer this high level is maintained, the more rapid will be the subsequent decline.
>
> "If the demand for domestic iron ore should increase soon as a result of interrupted foreign supply, the open-pit ores will respond again but with increasing difficulty and in decreasing quantities as the reserves decline; higher output for any particular year is always at the expense of the ability to expand in subsequent years.
>
> "Concentrates from lean ores are expected to make up the greater part of the Lake Superior production after the decline in open-pit ores and before concentrates from taconite expand beyond

the 25 million ton level. Reserve information on these raw ores is uncertain, as it is expected that output cannot be maintained for a long period.

"Southeastern States, principally Alabama, are not expected to increase their output beyond 10 million tons a year, because imported ore is counted upon to supply additional requirements. However, good possibilities exist for developing economic means to beneficiate the important reserves of low-grade materials and of discovering additional large tonnages of self-fluxing or partly self-fluxing ores similar to those now being used.

"Northeastern States, already producing premium-grade iron ore concentrates, are expected to maintain an output approximating 6 million tons per year. A sustained high demand will bring a few additional mines into production, but output in quantity from the many small deposits of siderate and brown ore await a considerable increase in price.

"West of the Mississippi River, the principal output has come from Texas, California, Utah and Wyoming, although iron ore deposits are known to occur in several other States. Distances, freight costs and increasing population tend to encourage the growth of an iron-producing industry in the West. However, evaluation of these possibilities is difficult.

"Inasmuch as it appears necessary for United States industry to go abroad for supplemental supplies of iron ore, it is fortunate that a good part of these supplies may be obtained from nearby deposits. Canada may be supplying nearly 40 million tons annually by 1975.

"Also nearby, yet subject to open-sea transportation, are the rich iron ore deposits of Venezuela. In magnitude they appear to be comparable to those of Quebec-Labrador. Security considerations favour the Canadian deposits, but year-round operation and premium grade favour Venezuela.

"Chile, Peru, Brazil and Cuba will provide additional supplies, but ores from Europe and Africa (with the possible exception of Liberia) will more probably find markets in Europe."

The United States Bureau of Mines forecast refers, in passing, to an important aspect of future Canadian production—one which may become more significant as the years go by. Generally speaking, the investments involved in opening up new Canadian mine capacity are less than those associated with the maintenance of production in the United States. Carrying charges on capital are therefore lower in respect to these Canadian operations. In

times when the steel industry is running below capacity, producers operating mines in both countries will be inclined to maintain the output from their more capital-intensive mines in the United States and to cut back production in Canada. Canadian (and to an even greater extent other foreign ores) will therefore be used to accommodate the swings in demand. Though they will meet a large part of the United States growth requirements, they may also be the first to feel the effects of periodic slackenings off in consumption.

To attempt to estimate Canada's overseas trade in iron ore is even more hazardous. Present indications are, however, that exports to Western Europe will continue to exceed by an appreciable margin the amounts shipped to steel mills in this country. In 1955, export sales to the United Kingdom, West Germany and the Netherlands amounted to about 2.5 million long tons. Arrangements are now being made for additional quantities to be shipped across the Atlantic each year in the early 1960's. More ore will go to overseas from Wabana in Newfoundland. Another three million tons of concentrates may move to steel mills in West Germany from Labrador. Considerable interest is also being shown in other Canadian deposits. Largely because of their high iron content, lack of impurities and promise of availability in times of shortage, demand from this quarter might double or even quadruple after 1965. Tentatively, total Canadian exports to Western Europe have been placed at 12 million long tons in 1980.

The only domestically produced ores that are available to the steel industry in the United Kingdom are low in grade. As elsewhere it may prove difficult to maintain, let alone improve, the present pig iron-scrap ratio. Greater steel output is therefore dependent upon a marked increase in imports of high-grade iron ore.[11] So, while the United Kingdom will continue to depend on Sweden and North Africa for about half of its total needs, other sources will also be required. Activity in this connection is reported in French West Africa and Sierra Leone. Some of them are even more distant from United Kingdom ports than the Canadian orefields. Investments in new capacity are also considered more secure in this country. These are among the reasons for believing that the United Kingdom may draw more heavily on Canada during the forecast period under review.

The steel industry in the other Western European countries, in total, is roughly twice as large as that of the United Kingdom. The latter's import requirements are presently in the order of 14 million tons a year; those of France, West Germany and the Benelux countries, taken together, about 25 million tons annually. Like the United Kingdom, they are also dependent upon imports of high-grade material from Sweden, Canada and North Africa. Exchange difficulties may persist. Still, Western European mills, because they thereby have access to a wider range of material, may also draw increasingly on the deposits of eastern Canada.

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[11]See *Development of the Iron and Steel Industry, 1953 to 1958* issued by the United Kingdom Iron and Steel Board in 1955.

Finally we come to the Canadian market itself. The Commission's own studies pertaining to the market for steel in Canada (see *The Canadian Primary Iron and Steel Industry*) indicate that pig iron output in this country may approximately treble over the next 25 years. Were this forecast to be realized, Canadian iron ore requirements might increase by approximately 200%. In 1955, shipments to the Canadian steel mills from all sources amounted to slightly more than five million tons. In 1980 they could be in the vicinity of 15 million tons.

Due to corporate, geographical and metallurgical considerations, imports from the United States, possibly to the extent of one-third of total Canadian consumption, may still be required a quarter of a century from now. In rounding out this study, it was therefore assumed that some 10 million tons of Canada-produced iron ore would be consumed in blast furnaces, open hearths and electric furnaces in this country in 1980.

Table 6 summarizes these forecasts and includes estimates for 1965.

Table 6

ESTIMATED PRODUCTION, CONSUMPTION AND TRADE IN IRON ORE, CANADA, 1955-80

(in millions of long tons)

Year	Mine shipments	Exports U.S.	Exports Europe	Exports Other	Imports	Domestic consumption
1955	14.6	10	2	1	4	5.6
1965	55.0	40	8	2	5	10.0
1980	85.0	60	12	3	5	15.0

Value figures can be obtained by multiplying the quantity estimates by the average estimated price per ton. Over the years the price of iron ore, while it has moved upward, has risen roughly in line with that of most other goods and services. As reported elsewhere (see Chapter 4) the real price of iron ore has remained relatively unchanged since 1900. Assuming a continuation of this trend, the valuation of Canadian production, exports and imports in 1965 and 1980 is therefore determined by the volume movements which are assumed to occur over the next 10 and 25 years.

Table 7

ESTIMATED PRODUCTION, CONSUMPTION AND TRADE IN IRON ORE, CANADA, 1955-80

(in millions of dollars)

Year	Mine shipments	Exports U.S.	Exports Europe	Exports Other	Imports	Domestic consumption
1955	110	80	16	4	32	42
1965	440	320	64	16	40	80
1980	680	480	96	24	40	120

(d) Corporate Structure of the Industry

The pattern of iron ore deposit ownership and exploitation on the North American continent has a distinct bearing on the character of the Canadian industry. Only a comparatively small tonnage of iron bearing material is traded on the free market. The consuming iron and steel companies own, wholly or in part, their own sources of ore; either that or they are engaged in long-term contracts with the merchant companies. Tonnage requirements are large and, with the increasing need for beneficiation and other treatment or the necessity to extend rail and other transportation facilities, the capital costs are becoming such that only the larger companies or a combination of companies can finance the type of development currently taking place in Canada.

Another feature of iron ore financing and marketing is born of the desire of the consuming iron and steel companies to ensure themselves of a long-term supply of ore. They accomplish this by participating in the financing of individual properties and they receive annual iron ore shipments from these properties on the basis of percentage stock participation. Any further deficiency is made up by long-term contracts.

The chemical and physical characteristics of iron ore have a pronounced effect not only on iron ore marketing, but also on deposit ownership. Uniformity of the blast furnace charge is obtained by blending ores from a number of deposits. To be successful, this blending at the furnace requires, in turn, considerable uniformity in the ores employed. Uniformity can be obtained by the receipt of regular shipments of ore from certain specific deposits; this is assured by whole or partial ownership, or by long-term contracts.

Cross-flows between one country and another are, therefore, inevitable. Based on sound economic consideration, they are likely to increase both in volume and complexity. A new pattern of trade is therefore being woven—a pattern based on the increasing vertical integration of the steel companies and their producing mines. This, as much as anything else, will help to maintain continuity in Canada's export sales of iron ore.

Of the 14 companies currently operating or actively developing iron ore properties in Canada, 10 are directly or indirectly controlled by United States interests. Of the total production of about 15 million long tons during 1955, over 70% was produced by companies controlled by United States interests. This percentage will probably increase to between 80% and 90% within the next 10 years. This control is in direct relation to the supply of capital funds for the development of the industry and this, in turn, is directly related to the market for the ore.

The ownership and control of raw material sources by the primary iron and steel industry is part of the historical and operational fabric of the indus-

try. Traditionally, it has taken little account of national boundary lines; in particular, the International Boundary line between Canada and the United States. A few details on the sources of raw material supply of specific companies will indicate clearly that this ownership of primary iron and steel raw material resources in one country by the other is by no means onesided.

The Steel Company of Canada Limited, from the very day of its inception as a primary producer in 1895, has drawn all its coal and about half its iron ore from jointly-owned mines in the United States.[12] This has been a logical consequence both of the company's location at Hamilton, Ontario, and of the fact that there are no Canadian sources of coking coal within economic distance of Hamilton and, until recently, no Canadian sources of iron ore. As for limestone, the Steel Company of Canada owns its own sources of supply in Canada.

Algoma Steel Corporation Limited, since very shortly after its inception in 1901, has drawn about two-thirds of its iron ore, all its coal and a large part of its limestone from wholly or partly-owned mines in the United States.[13] Once again, this has been a logical consequence of the company's location close to established American sources and of the lack of an economic source of coking coal in this country.

Dominion Foundries and Steel Limited at Hamilton has been a producer of pig iron only since 1951 and has not yet acquired control of its own sources of raw materials supply. Currently, American iron ore is purchased on a long-term contract basis. It purchases its coking coal in the United States.

Dominion Steel and Coal Corporation, from the day of its inception as a primary producer in 1899, has drawn almost all its iron ore from the company mines at Wabana, its coal from company mines in Nova Scotia, and its limestone from company mines in Nova Scotia and Newfoundland.

Steep Rock Iron Mines Limited exports almost all its production to the United States. This practice is based on two main factors; the ore is exceptionally high in grade and is, therefore, employed essentially for blending purposes (hence the market for it is relatively small in Canada) and the company has a very close relationship with a number of American companies. Premium Iron Ores Limited is the exclusive sales agent for Steep Rock ores. Premium in turn is owned by Cyrus Eaton and Cleveland asso-

[12]The Steel Company of Canada draws its iron ore from a number of jointly owned mining companies located principally in the United States. Their names, together with the proportions of Steel Company of Canada ownership, are as follows: Balkan Mining Company (33 1/3%); Hoyt Mining Company (15%); Lake Mining Company (12 1/2%); Utica Mining Company (16 2/3%); Western Mining Company (50%); Mauthe Mining Company (25%); Fortune Lake Mining Company (50%); Palmer Mining Company (10%); Eire Mining Company (10%); and the Hilton Mine at Bristol, Quebec (50%). Source: ***Report by the Tariff Board Respecting Basic Iron and Steel Products,*** Queen's Printer, Ottawa, February, 1957.

[13]Algoma does not own any iron mines in the United States. Hence, it must purchase much of its ore from other companies. In recent years, between 25% and 30% of its ore requirements have been forthcoming from its own Canadian mines. The rest originates with mines operated by other firms in the Lake Superior region of the U.S.

ciates. Inland Steel Company has large iron ore reserves in the Steep Rock Lake area of Ontario, consisting of the "C" ore zone of Steep Rock Iron Mines which it has leased on a royalty basis for 99 years. Inland's operations are conducted by the Caland Ore Company Limited, a wholly-owned subsidiary of the Inland Steel Company of the United States.

The Iron Ore Company of Canada brought the large Labrador-New Quebec deposits into production to supply, primarily, the American companies which financed the development—Hanna Coal and Ore Corporation, Republic Steel Corporation, National Steel Corporation, Armco Steel Corporation, Youngstown Sheet and Tube Company, Wheeling Steel Corporation.[14] In turn, this assurance of supply was the incentive which brought about the financing. If American iron and steel companies had not guaranteed a market for the ore, this development would not have taken place.

United States Steel Corporation intends to develop its huge deposits at the southwest end of the Labrador-Quebec iron belt for the specific purpose of supplying its plants in the United States.

Bethlehem Mines Corporation has brought its Marmora, Ontario, mine into production to supply the Lackawanna, New York, mills of its parent company, Bethlehem Steel Corporation. Meanwhile the Steel Company of Canada Limited, together with Pickands Mather and Company of the United States have undertaken a joint development of the old Bristol Mine, now known as The Hilton Mines, 35 miles northwest of Ottawa. This ore, in the form of pelletized magnetite concentrates, will be shipped by rail to both American and Canadian steel mills. Lowphos Ore Limited, a wholly-owned subsidiary of National Steel Corporation of the United States, is developing an iron ore property at Moose Mountain, 35 miles north of Sudbury, for initial production in 1958. The property will be operated by the M. A. Hanna Company, Cleveland, as agent for Lowphos Ore and production is planned at an annual rate of 500,000 tons of iron concentrates.

It is apparent from the foregoing examples that the organization of the Canadian iron and steel industry is an integral part of the organization of the primary iron and steel industry, especially in the United States, and to a

[14]The percentage stock ownership of the Iron Ore Company of Canada as of June 30, 1954 was as follows:

Company	*Percentage ownership*
Hollinger Cons. Gold Mines	8 1/3%
M. A. Hanna	8 1/3
Hollinger North Shore Expl.	10
(60% owned by Hollinger Cons. and 40% by Hanna Coal and Ore, subsidiary of M. A. Hanna)	
Labrador Mining and Expl.	6 2/3
(51% owned by Hollinger Cons. and 18% by Hanna Coal and Ore, with remainder public)	
Hanna Coal and Ore	18
(59% owned by M. A. Hanna)	
Armco Steel	6 2/3
National Steel	13 1/2
Wheeling Steel	5 1/3
Republic Steel	16 2/3
Youngstown Sheet and Tube	6 2/3

much lesser extent in Canada. That it is more an integral part of the American organization than of the Canadian organization is due entirely to the provision of a much larger market for the iron ore by the primary iron and steel industry in the United States. Finances for the exploitation of specific deposits are in turn a direct outcome of market provisions. These two statements, simple as they are, indicate the two principal conditions which provide the basis of the organization of the Canadian iron ore industry.

(e) *Financing and Development*

Iron ore is produced, moved and consumed on a large volume basis. In order to keep unit costs to a minimum, heavy investments in plant and equipment are involved. Though they vary, depending on the nature of the deposits, the extent to which they require on-site treatment and the need to install new transportation facilities, they often run into hundreds of millions of dollars—capital outlay equal to or larger than those required in the establishment of most other types of mining enterprises.

That which is needed at the outset varies considerably from one project to the next. Some ore deposits are buried more deeply than others. Hard material must be crushed and the lower-grade ores must be processed to raise their iron content to an acceptable minimum. Sometimes impurities must be washed away or, like sulphur, removed by sintering. Preparation in suitable agglomerated form, though it may be accomplished simultaneously, involves further outlays on plant and equipment. Where existing rail and ocean or lake shipping connections exist, new investments in respect to transportation can be held to a minimum. On the other hand where an entirely new mining area is being opened up, the opposite tends to be the case.

In this country, capital outlay per ton of initial capacity has varied considerably. From a low of around \$10 per ton (e.g. the opening up of the Hogarth open pit at Steep Rock) they have ranged to upwards of \$25 per ton as in Quebec-Labrador. So far only one Canadian development (that of The Bethlehem Mines Corporation of Marmora) has involved outlays comparable to that reported for the taconite beneficiating plants now being installed in the United States. Producing specially prepared pelletized iron ore concentrates containing upwards of 60% iron, the latter range between \$40 and \$50 per long ton of capacity.

Unit capital costs are not the whole story, however. Other economic factors must also be taken into account when assessing the profitability of each venture. Among them are the location and extent of the proven iron ore reserves, their iron content, their amenability to beneficiation and the behaviour of the resultant product in the blast furnaces and open hearth of the parent steel company.

An assured long-term market is also essential to the development of most iron ore properties. Usually this takes the form of ownership, in whole or in part, by one or a group of companies in the iron and steel industry. Only in exceptional circumstances has it been possible for independent companies to raise the necessary funds by negotiating special contracts with the steel companies for the sale of iron ore.

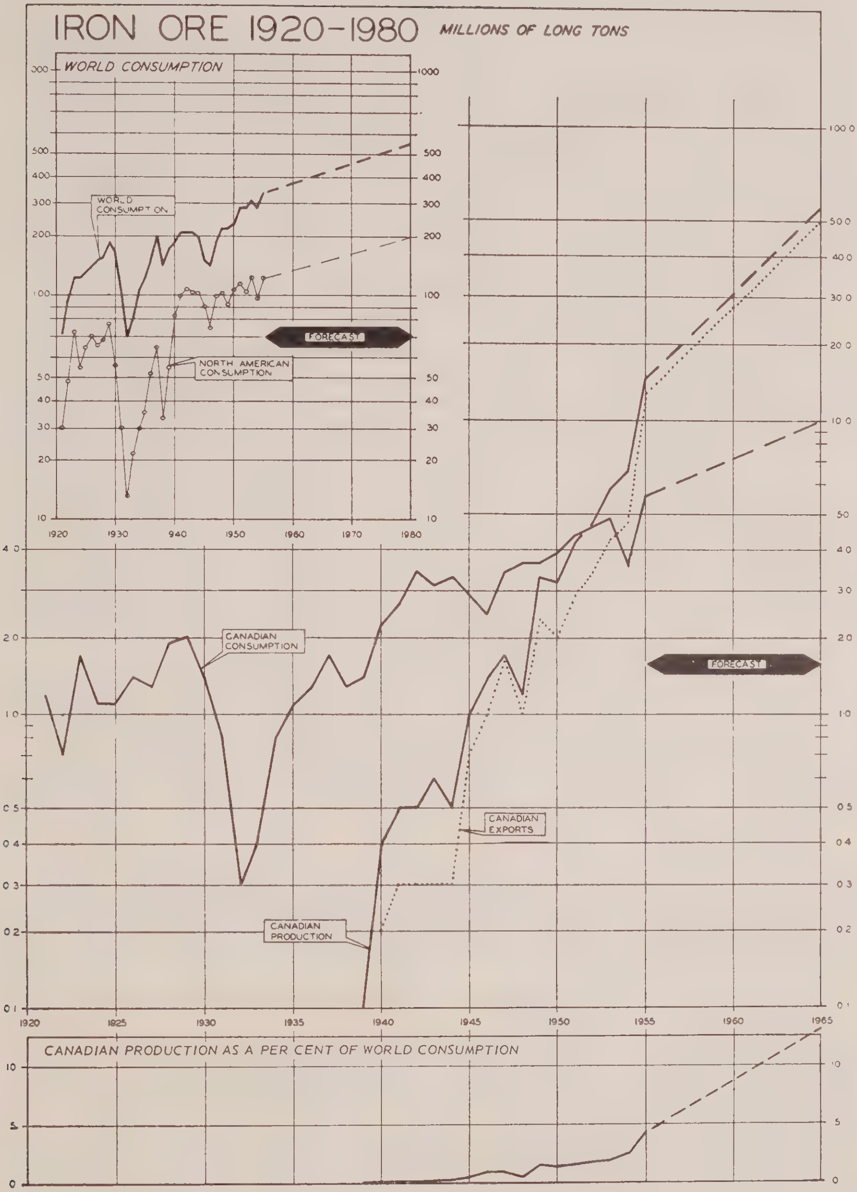
The financing of most iron ore developments in Canada since 1945 has been made possible through the sale of bonds, through cash advances from parent companies and by stock purchases made by the major steel firms and their mining company subsidiaries. Little capital has been raised by the sale of common or equity stock to the general public. As a result, the ownership and control of the Canadian iron ore industry rests essentially in American hands.

As in other types of mining, this industry has been able to take advantage of the three-year period of exemption from income tax first introduced in 1935. Assistance in the form of railway and dock construction and a five-year rebate on transportation charges was provided for Steep Rock Iron Mines by the Canadian National Railways and the Federal Government. Also being a primary industry, iron ore mining, treatment and transportation has been able to take advantage of the 99% duty rebate provision of foreign produced materials and equipment which are characteristic of Canadian federal legislation. In respect to import duties under the Ontario Iron Ore Bounty Act, production in the Michipicoten area was subsidized for four years. Roads, power producing facilities and other services have also been provided these and other iron ore mining projects by the Canadian federal and provincial governments.

(f) *Conclusion*

Iron ore of grades and in quantities sufficient to meet the expanding requirements of North American steel mills can no longer be found within the confines of the United States. For this reason iron formations in Ontario, Quebec, Newfoundland and Labrador are being opened up. It is also due largely to their strategic importance that the St. Lawrence Seaway is now being completed.

In 1980, some 80 million long tons of iron ore may be produced annually in Canada. Though the bulk of this output will go to the United States, shipments will also be made to Canadian mills and overseas to Western Europe and the Orient. Valued at more than $600 million a year, the output of this industry will then be comparable in size to those producing nickel or copper in this country.


IRON ORE 1920–1980
MILLIONS OF LONG TONS
WORLD CONSUMPTION
WORLD CONSUMPTION
NORTH AMERICAN CONSUMPTION
FORECAST
CANADIAN CONSUMPTION
CANADIAN EXPORTS
CANADIAN PRODUCTION
FORECAST
CANADIAN PRODUCTION AS A PER CENT OF WORLD CONSUMPTION

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C. Nickel

(a) *General Introduction*

Nickel is one of the largest of all Canada's non-ferrous metal mining and processing industries. Canadian nickel production was valued at $223 million in 1956, copper at $291 million and aluminum production at $300 million.

For more than half a century Canada has been the world's leading producer of nickel. This position has been based in part on her exceptionally rich reserves of ore, and in part on the economical processes and plants for mining the ore and extracting nickel from it that have been developed by the Canadian producers. Canada is being helped in maintaining this dominant position by the great current activity in locating and developing new ore bodies and providing the plants to extract nickel from them. At the same time, she is being challenged more and more by a very large expansion in production in foreign countries, not only by the older organizations, as in

New Caledonia, but by the new ones springing up in Cuba with the stimulation and help of the United States government. The New Caledonia ores are richer in grade of nickel content and the Cuban ore bodies are larger in extent than those discovered so far in Canada. Canada's ability to retain its position in nickel will be helped greatly by the richness of her resources and by a continuation of strong efforts of Canadian companies to hold down their costs, maintain the superior level of quality of their products, hold their present markets and develop new ones for Canadian nickel by intensive research and market development activities. All of this will require, the producers emphasize, the maintenance of a favourable economic atmosphere, particularly as this may be affected by dominion and provincial fiscal policies, and the continuation of friendly and productive relations between management and labour.

Canada can face the future in nickel with confidence based on its substantial resources, the strength of its producers and the position as suppliers they have achieved with users of nickel throughout the world.

Not so long ago there was a feeling that the difficulties in treating the more abundant lateritic ores, such as in Cuba, would put off for a decade or so any substantial challenge to Canada's dominant role in the production and export of this vital alloying and electroplating[15] material. But development in this field has occurred very rapidly.

Satisfactory processes are already being used for treatment of the Cuban Nicaro ores, and other processes have been developed for the Moa Bay ores to be handled by the Freeport Sulphur Co. Both of these Cuban producers have stated publicly that they can treat the Cuban ores at costs that would show a satisfactory profit at prices below the current (74¢) United States market price for nickel. One firm is also negotiating contracts to sell nickel up to 1965, extendable for the same quantities up to 1970, at the present United States market price plus only 80% of any increase over this price. Consequently, if this price should rise with increasing labour and other costs, this Cuban producer could be, by contract, underselling the Canadian price and thus entrenching himself in the market. This possibly lower price for Cuban nickel presumably reflects the ease of mining the lateritic ores which are surface deposits and the much lower standard of living and labour rates in Cuba as compared with Canada.

The extent to which Canada's 80% to 85% share of the free world's market for nickel may be reduced by the greater production of foreign nickel during the next few years can be shown by the following statistics for free world production in 1961 from operations already in hand or specifically projected:

[15]Uses include—iron alloys, 49%, non-ferrous alloys, 31%, plating, 17%.

Source of nickel	*Projected 1961 production short tons*	*Percentage of total*
Canada—sulphide ores	237,500	70
Cuba—lateritic ores	50,000	15
New Caledonia—lateritic ores	32,500	10
U.S.—lateritic and other ores	10,000	3
Others	7,500	2
Total	337,500	

While Canada's share of the world's trade will be reduced as indicated, its volume will increase substantially. Also, the structure of the industry is due for further changes. As recently as 1950, the Sudbury district of Ontario was the sole source of Canadian production. One company operating there, International Nickel Company of Canada Ltd., alone accounted for more than 90% of the nation's total output of ores, concentrates and refined metal. Since then, nickel mining has commenced at Lynn Lake in Northern Manitoba and refining near Edmonton, Alberta. Sherritt Gordon Mines Ltd. has thus joined Inco as a fully integrated producer in this country. Another extensive operation in Northern Manitoba has just been started by Inco in the Mystery Lake and Moak Lake areas, which will include complete mining, smelting and refining installations, and is expected to increase Inco's nickel output by about 30% in 1961. Falconbridge Nickel Mines Ltd., long active in the Sudbury area, has several processes for nickel concentrates (or matte) under review. Independently, a copper-nickel custom smelter is being planned for the Chicoutimi region of Quebec. Numerous properties, ranging from the Northwest Territories to Western Ontario and from thence through Sudbury to the tip of New Quebec are under active investigation by these and other companies. There is every indication, therefore, of wider geographical distribution, as well as more extensive processing of nickel in Canada in the 1960's and 1970's.[16]

Canada is by no means alone in this. Two projects in Cuba have been mentioned previously. The one at Nicaro[17] is a revival of the Allied efforts during World War II to win supplementary supplies of nickel, and is now being expanded; the other is at Moa Bay[18] and, while still in the pilot plant stage, is expected to be in production before long. Both are sponsored in one way or another by the United States government and appear to have an assured long-term market for their output with the United States stockpiling

[16]In 1955, Canadian company production was divided approximately as follows: Inco 140,000 tons; others 35,000 tons.

[17]The Nicaro deposit is being operated by the Nickel Processing Corporation, a subsidiary of National Lead Co., for the United States government and it draws its ore partly from lands owned by the Nicaro Nickel Co., a subsidiary of the Freeport Sulphur Co. in the Levisa Bay area.

[18]The Freeport Sulphur Co. announced the erection of processing plants both at Moa Bay in Cuba and near New Orleans, the purpose of which is to treat Cuban ores in a complementary fashion for the recovery of nickel and cobalt.

authorities in the event that they should be unable to dispose of their product directly to industrial users. More than that, they will continue to provide a focal point for research into the extraction of nickel and valuable by-products such as chromium, cobalt and iron from the extensive ore which is known to occur throughout that country.

In the United States, traditionally a nickel-poor country, a continuing shortage, together with government contracts at high prices have led not only to increase recovery from scrap but also revived an interest in deposits which might otherwise have lain idle for centuries. Not only is nickel being recovered increasingly as a by-product of copper production but at least one property—at Riddle, Oregon—has been opened up as a source of ore and concentrates.[19] Outside the Western Hemisphere, other sources are either maintaining their output or are in the course of being expanded. The New Caledonia mines off the northeast coast of Australia, which have been worked for nearly a century, show no signs of lagging in their activity; in fact, projected facilities for increased production would bring the total from New Caledonian ores to 32,500 short tons by 1961. The U.S.S.R. has been increasing its output of nickel from its various mines including those of Petsamo in Finland, developed by Inco and seized by Russia from Finland in 1944. By-product metal, though relatively small in quantity, is increasing in amount from South Africa. This additional volume, together with the construction or expansion of nickel refining and processing facilities in the United States, United Kingdom, France, Norway, Russia and Japan are adding not only to the volume but also to the complexity of international trade in nickel and its various primary products.

During recent years, the nickel industry has been in what must be considered a highly favourable position even though the advantages that go with a demand greater than the available supply have been tempered by the restraints in developments of future markets imposed by such a situation. Metal prices which for nearly a quarter century fluctuated around the 35¢ level have edged steadily upward since 1949. At present, 74¢ in the United States (and reported to be $1 or more a pound in the case of a number of special United States stockpiling and other defence contracts), they have rendered a number of previously discovered properties economic; at the same time they have hastened the search for others. Volume requirements also have been rising. After having dropped to a post-war low for free world deliveries of 135,000 tons in 1946, they subsequently passed the World War II peak in 1953 with deliveries that year of 167,000 tons. In 1955 deliveries in the free world were 213,500 tons with a Canadian production that year of 175,000 tons.

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[19]In the United States, two nickel occurrences are under development, one at Fredericktown, Missouri and the other near Riddle, Oregon. The former is a complex lead-copper-nickel-cobalt sulphide, the other a silicate ore. Production from Fredericktown is planned at about 900 tons annually; the yearly output of the latter, a ferro-nickel alloy, at 7,000 to 9,000 tons of contained nickel. Scrap recovery in 1955 supplied 11,540 tons (or about 10% of total consumption).

Yet with the continued pressure of defence buying and defence priorities, certain civilian applications are being reduced, others eliminated entirely.

Substitutions in the form of new alloys and other alloying elements are creeping in. Heavy investments, to accommodate substitute materials and which will have a lasting effect upon the future receptivity of industry to nickel, are being made. These, too, will tend to restrict the commercial demands for Canadian production once the priorities set by governments have been abandoned.

Yet a solution by way of new capacity for increased production is also in sight. As shown by statistics for 1961 production cited previously, present schedules will bring free world production up to 337,500 tons. Five years from now Canadian mines alone may be capable of producing over 235,000 tons of contained nickel in ores and concentrates; Cuba may be capable of producing at least 50,000 tons of nickel in nickel oxide and more refined forms; New Caledonia may be contributing some 32,500 tons; the United States something like 10,000 tons and Greece, South Africa and others another 7,500 tons. All told, it looks as if there will be an increase of about 60% in nickel output available for consumption in the free world between now and the early 1960's.

Timing, of course, is important. Demand, by then, may have been moderated by a diminution of defence requirements. Will this result in a serious dislocation of the industry, particularly the nickel industry in Canada? Or will the Canadian producers, as in the past, adapt themselves to their new found circumstances? Will they turn within a short period of time what otherwise would have been a serious setback, into an even greater measure of stability for the future?

(b) *Long-Term Trends*

Here, then, is the focal point of our enquiry. What is likely to happen as and when the accumulated defence demands of the western world and purchases for stockpiling begin to drop off? Will the commercial market be able to take over smoothly and efficiently? And, having regard to Canada's particular interests, what are the possibilities by then of increased competition from newly developed sources in other parts of the world? While there is little which can be said with assurance on any of these matters, some discussion of the possible order of magnitude and the lessons which can be learned from the past have merit here.

We are told that in 1955 defence requirements and stockpiling absorbed about 40% of all new nickel production. A large part of this was "consumed" in the sense that it was being used up by industry in the production of jet aircraft, guided missiles, armoured vehicles, other motor transport, naval

vessels and the like. The remainder, however, was merely being accumulated against future defence emergency needs. It was being stockpiled, in the main, by the defence authorities in the United States with the twin objectives of securing a large inventory of metal immediately usable in any emergency and of creating surplus capacity at the primary level which could be drawn on as required. As mentioned later, the United States government has suspended stockpiling of nickel in 1957. Barring some unforeseen development in the international situation, it seems unlikely that stockpiling of nickel will have to be resumed so long as demands for current defence and civilian uses require all, or substantially all of the available supplies. But the fact that such defence purchasing is and may continue to be subject to vacillations has also made it a matter of concern to those parts of Canada in which nickel mining and processing provide the major, if not the only source of employment and income.

Over about the next two years, the ordinary commercial export market may continue to be restricted, one might even say rationed, to a level of consumption generally characteristic of the period from 1948 through the Korean outbreak. Then, or afterwards, most of the increased production available from Canada, Cuba and the United States could be thrown upon a civilian market ill adapted to the distribution of such a volume of new metal. In the United States alone, ordinary commercial channels might be called upon to manage an upward of 50% increase in civilian nickel supply. This is not something which can be done over night. Indeed, should business activity show signs of slackening, the producing countries, and this applies with particular force to Canada, would be in serious straits indeed. The results, of course, would be calamitous if accumulated stockpile metal should be dumped on the market in competition with current production.

To assume such happenings is, perhaps, to take an all too pessimistic view of things. Upon enquiry, the United States authorities have stated their intention of withdrawing in a more graceful fashion from the market. Such a declaration is repeated in the United States Department of Commerce *Review* of July, 1955. In it we read, "It has long been the Government's policy to taper off its purchases for Government account as it reaches completion of a stockpile goal. This will be done so that the Government may withdraw from the market gradually rather than abruptly. The Government does not consider it to be good policy to continue its procurement full blast until the last ounce of stockpile has been acquired, and then, abruptly leave the market to absorb the shock of Government withdrawal all at once. Accordingly, beginning sometime after January 1957, the Government is likely to be more inclined to withdraw from the market in favour of industrial demands, provided national security requirements at that time permit this to be done."

This stated policy has been adhered to. On March 31, 1957, the Office of Defense Mobilization stated, "The Government will not need any nickel for the stockpile through the end of this year. Previously the O.D.M. had indicated it would make no calls on nickel output through June."

Another official source—a United States Bureau of Mines publication entitled *Mineral Facts and Problems* issued in 1956—is somewhat more forthright, though less reassuring in its remarks. It says, "Following the expansion programme, the capacity to produce nickel will exceed peacetime needs. Severe restrictions on uses of nickel and emphasis in public announcements on its scarcity have served to retard the development of new markets. It is believed that the pre-Korean peacetime trend in consumption of nickel will project itself into the post-emergency period and that, within ten or fifteen years, markets will be found for most of the expanded output of the current defense program."

Again, "The foremost problem confronting the nickel industry is the great disparity between peace and war requirements. An industry geared to peaceful requirements is entirely inadequate to meet war needs. On the other hand, an industry expanded to supply war demands finds itself with an enormous burden of excess capacity when peace is re-established." The Canadian industry, in other words, must adjust itself to a new set of circumstances—a period, possibly in the early 1960's, when, as a result of the United States government stimulated expansion programme directed to Cuba and elsewhere, surplus capacity will be looking for markets for old and new applications in order to maintain its current level of prosperity.

To the nickel industry this is nothing new. Throughout its varied lifetime, it has been faced alternatively with the task of trying to build up commercial markets and subsequently having to deny its hard-won customers metal which government priorities—and particularly those of the United States government—dictated should go elsewhere.

It has been Canada's nickel industry that has successfully supplied allies with all the nickel required for all military and essential civilian needs during two world wars. During the cold war, starting with Korea, Canada has provided enough nickel for free world defence needs plus stockpiling, though not enough for all civilian demands as well.

During peacetime, the supply of nickel has been plentiful. Most strenuous research and market development efforts have been made to create and expand markets which seldom have taxed Canada's capacity to produce nickel.

History, in this respect, has repeated itself several times over. On each occasion, the adjustment, though still painful, has been less drastic than the last. The reason is that the hard core of opportunities for commercial utilization of nickel has continued to grow along with nickel's contribu-

tion to defence. There is in this an important inference for the future. It suggests that the reversion to the peacetime markets of the 1960's should involve less of a let down than that which occurred immediately after World War II—and much less damaging than that which occurred soon after 1918. Another difference is that the servicing of defence requirements may be spread over a much longer period; ten years rather than four or five. Thus, with a dropping off in non-commercial allocations, the exceptional increase in capacity which is now in sight may be the better accommodated than at any time previously.

That the industry is capable of ultimately overcoming these periodic diseconomies of idle plant and unemployment is hardly open to doubt. This capability was demonstrated after World War I ended, but it took a number of years then and will be at least as difficult in the future by reason of the presence of a larger number of competing materials, and the appearance of foreign nickel producers who will add to the supply without any present assurance that they will be inclined to make any substantial contribution to the effort required to find a market for it. Nevertheless, a review of what happened after World War I will serve as an example for the future.

When World War I ended, the market for Canadian nickel in armaments and munitions was largely wiped out. With only 10% of its larger outlets remaining, the Canadian industry was confronted with the same problem which it had faced a quarter of a century earlier—that of building up a volume of commercial demand commensurate with its recently won ability to produce new metal.

A few civilian markets remained. Nickel silver, a copper-nickel-zinc alloy was already popular as a base metal for silver plating. The use of nickel coinage was becoming general. Canada adopted it for the first time in 1922. Steels, strengthened by the inclusion of nickel, were becoming more popular for automobile parts and other machinery. These all-time uses which had, for a period, been subject to strict rationing, were quickly revived.

New demands of even larger volume were soon to emerge as a result of intensive market and technological research. During the War, the armed forces had demanded strong, tough steels. To meet their rigid specifications, the war industries had recruited the help of many of the most skilled metallurgists and hastily trained others. As a result of this growing knowledge, some of the advantages of using nickel-bearing alloys began to be appreciated.[20]

Besides, the growth of industrial activity, which characterized the late 1920's provided a momentum of its own. With the insistent demand for better and more durable machinery and equipment, nickel was, sooner or

[20]In the 1890's, the property of hardening steel first began to be exploited; in the 1920's the emphasis shifted also to alloys of high corrosion and temperature resistance.

later to find its niche. The automobile, subject in its earlier years to stripped gears and broken axles, gradually developed a greater dependability through the designer's judicious use of tough nickel alloy steels. The radio industry added to the demand, as did the increasing mass production of a variety of electrical appliances. In Germany, Krupp introduced the austenitic "stainless" steel and, in the United States, Western Electric developed "Permalloy" for use in communication systems. Architectural changes, together with the peculiar needs of the fast growing chemicals, metallurgical, oil and other processing industries, also began to place a premium on strength and more corrosion-resistant materials. Thus nickel was able to regain substantially its peak World War I position before the Great Depression set in.

Anchored as its markets were to the fate of the capital and consumer durables industries, the fortunes of the nickel industry were bound to be determined, in no small measure, by the unpredictable swings of the business cycle. Output dropped more than 70% between 1929 and 1932.

Across the Atlantic, the recession was less drastic and somewhat shorter lived. Recovery of markets in Europe after the low point in 1932 served, therefore, by 1933 to restore the total consumption of nickel to the levels reached between 1925 and 1929. The eventual recovery in the North American market, along with continued improvement in the European market, resulted in pushing consumption in the period 1935 to 1939 to over double what it had been ten years previously. The expansion in the European markets during this period no doubt included consumption for military purposes, but even in 1939, regarded as the year of greatest military preparation, the percentage used for such purposes was reported by the principal producer as being not more than 15% of the total.

World War II, like its predecessor, swept the industry to new peaks of emergency production. Yet, as before, it brought fresh problems. Government controls, even more efficient than before, were exerted over both production and distribution. Sales for purely civilian purposes were strictly limited. Strenuous attempts were also made to increase supply. A number of old deposits were reopened and production was accelerated from the existing underground mines and greatly enlarged open pits in this country. Also, in 1943, the Cuban deposits were brought into operation by the United States government. The end of hostilities saw the re-emergence of the now familiar pattern. The industry had to cut back its operations, International Nickel alone by about 30%. This time, however, the commercial importance of nickel was better understood. By 1948, civilian demand, with its growing emphasis on automotive equipment, industrial machinery, stainless steel, and the home owner's seemingly insatiable appetite for consumer durables quickly provided a market matching the capacity for production. The greater use of stainless steels and other nickel alloy steels, particularly in the pro-

cess industries, also helped, so much so that by 1948 production had risen by nearly 35% over its 1946 low. Settling back a bit in 1949, the industry was again approaching capacity when the Korean incident began to have international repercussions in 1950.

This historical resumé has helped to identify some of the strong underlying factors, characteristics of demand which can be expected to respond to efforts to assure markets for ever increasing quantities of nickel as the years go by. An examination of statistical relationships is also rewarding. While nickel sales have fluctuated more or less with steel production, they have, on the average risen at about the same rate.[21]

As will be brought out in a later discussion, it will be necessary to achieve a higher rate of increase in the consumption of nickel in civilian applications if such uses of nickel without any requirement for defence are to be able to absorb the projected increase in production in the 1960's. On the optimistic side will be the greater ability of nickel to compete with such other additive metals as chromium and molybdenum when nickel has been freed from the limitations on development imposed by its short supply in recent years. It will be able to hold the line more firmly in the future, once more being designed into rather than out of many a structural material or item of machinery and equipment.

The long-run world consumption curve, despite its irregularities, shows little indication of a slackening in demand. Since the early 1920's over-all requirements have risen at an average rate of 5% per annum; that is, they have doubled every 14 years. A yearly growth rate of 3% or 4%, when used for forecast purposes, appears reasonable — even cautious — in this light. Four per cent a year, based on 1955, leads to an annual demand for new metal in 1980 in the order of 650,000 short tons. Various authorities in and close to the industry believe a supply in this order of magnitude will, by then, be forthcoming with little or no change in real price.[22] This figure, together with one pertaining to a world consumption in 1965 of 400,000 tons, has therefore been adopted for forecast purposes in this study.

It is possible, however, that defence requirements may be sharply reduced over the next decade. Were this to be the case, our mid-term (1965) figure will probably be on the high side. This important qualification can be borne out by a more detailed analysis of the demands for new metal which may emerge over the next ten years.

Since the factors of interest with respect to growth of civilian uses of nickel are not applicable to defence uses, it is necessary to deduct the amount

[21]Since 1920, the long-run increase in consumption of steel on the continent has been in the order of 3% per annum.

[22]See H. J. Fraser, *Current Trends in the Nickel Industry*, Conference of Provincial Ministers of Mines, Lake Louise, Alberta, September, 1956.

used for defence in 1955 (40% of the total) from the total free world use to provide a base line for projection of future free world civilian demand.[23] It is necessary also to make another adjustment to take into account the latent demand for nickel for civilian uses in 1955 that could not be satisfied from what was left when the defence needs were met. A figure for this latent demand in the United States is provided by the estimate in the Townsend Report[24] of 15,000 tons. The latent demand in the rest of the free world was probably less but so as to err on the optimistic side in figuring the total, it is assumed to be another 15,000 tons to make a total free world latent demand of 30,000 tons in 1955.

The final base figure for 1955 civilian demand then becomes 158,100 tons.[25]

A 5% rate of annual increase in consumption would result in a free world demand for civilian purposes of about 258,000 tons in 1965 and about 535,000 tons in 1980. The amounts that should be added to these figures for defence and stockpiling are necessarily uncertain. In the light of present United States policies, it may be assumed that there will be no requirements for stockpiling in 1965. How much to include for defence alone at that time can be estimated on the basis of current (1957) free world defence requirements which represent somewhere between 20% and 25% of free world deliveries. It seems likely that there will be a downward trend in defence need, so that using the lower figure indicates that a provision of 40,000 tons per year should be ample for defence requirements in 1965. On this basis, the estimated total free world demand in 1965 projected from 1955 at a 5% annual rate of increase for civilian uses would be 298,000 tons and in 1980, 575,000 tons. The Paley Report predicted a free world requirement of 264,000 tons in 1975. These estimates indicate that we should reach the level of consumption more than ten years earlier than predicted in the Paley Report.

A 1965 consumption of 298,000 tons is about 40,000 tons short of the production in sight by 1961. This probable excess of supply over demand should be stimulating to consumers considering new and enlarged uses of nickel for civilian purposes. At the same time, it poses a problem to the producers in finding a market for the increased supplies that will be available. This problem is complicated by the fact that the greatest addition to the supply will occur rather abruptly in the 1960-61 period. In the meantime, the elimination of stockpiling and a possible reduction in defence re-

[23]Russian production and use are left out of this discussion since no reliable figures are available and since Russian production and use have no measurable effect on the free world nickel market.

[24]Report of December 31, 1956, by the Secretary of Commerce to Joint Committee on Defense Production issued January 8, 1957, p. 103.

[25]This is made up of two items:

60% of total free world consumption of 213,500 tons	= 128,100 tons
Latent civilian demand	= 30,000 tons
Total civilian demand	= 158,100 tons

quirements will result in a substantial increase in the amounts available for civilian use so that it will be possible to take some steps toward the ultimate goal of a much higher level of usage prior to 1960, even though the major increase in demand will have to be accomplished after the principal additions to supplies in 1960.

It is evident that a 5% annual rate of increase in consumption will not be high enough. This rate will have to be increased to 6.5%. From the standpoint of civilian users, it will be reassuring to know that the increased production capacity of the nickel industry will be such as to accommodate in 1965 a market that can increase at an annual rate of 6.5% above the 1955 level of true civilian demand.

The market for nickel cannot be depended on to expand pretty much on its own momentum. It will be necessary to exert even more intensive research and market development efforts to assure the enlarged markets that will be needed. Nickel is in constant competition with other alloying elements, other metals and non-metallic materials. Many of the new applications for which nickel may be used will require properties that can be obtained only in new alloys or improvements of present ones. Even further, some of the possible new markets, e.g. super-critical temperature steam power plants that can provide a market for nickel alloys will not be practical until the proper alloys have been developed.

The contribution to the necessary research and market development effort that may be made by foreign producers of nickel is uncertain. The Canadian efforts along these lines have been exerted almost wholly by Inco. Supplementary activity by the other Canadian producers would be very desirable in insuring that there will be a market for the enlarged future production of nickel in Canada and that Canada's share of the world market will continue to be a predominant one.

(c) *The Competitive Position of Canadian Producers*

The market for nickel, as we have seen, will continue to expand. Canada, with increased mine and processing plant capacity, will also supply much of the world's needs. However, this country's share of the total market 20 to 30 years from now will depend in no small measure upon the competitive position of the Canadian producers in the 1960's to 1970's.

To date, the Canadian industry has been in a virtually unassailable position. Besides nickel, they have been able to recover other and very remunerative metal values. Copper has been extracted from the same ores and marketed in comparable volume. Precious metals like gold and platinum and little known elements like selenium and tellurium have been isolated in appreciable quantities. Recently, high-grade iron pellets have been added to

the list. With this growing diversification of output, the profitability of the industry is less subject to the vagaries of the market than has been the case with many another mine producing a much more limited range of output.

This characteristic—one which has helped the Canadian mining industry to weather the ill effects of the business cycle in the past—will, doubtless, continue to be one of its principal strengths in the future. This, fortunately, applies not only to operations in the Sudbury district, but also, to a lesser degree, to those in northern Manitoba and elsewhere.

Contrast this with the present position in the world's other major nickel producing areas. True, in Cuba, cobalt is being recovered along with the nickel oxide there.[26] So far, attempts to extract the remaining cobalt and other metals, chiefly chromium and iron, have fallen short of commercial feasibility. As long as this continues to be the state of affairs, the Canadian industry has little to fear from large-scale commercial production in the tropical countries where the lateritic ores abound.[27]

Yet, defence consideration and the concerted effort on the part of the United States government authorities to become substantially independent of a single "foreign" source of supply (i.e., Canada) can and may have important repercussions. The United States Bureau of Mines, in particular, is making every effort to solve the metallurgical and associated problems connected with the large-scale treatment of the Cuban ores. Today, with the benefit of low interest government loans and special depreciation and other tax concessions, these mines can just about break even. Further significant advances, particularly in the field of pressure leaching, could well make the difference between subsidized and truly commercial operations in these latitudes. With this happening in the interval, substantial production could well be forthcoming from these sources 10 to 15 years from now.

One must not lose sight of the fact that in Canada the grade of the ore has been steadily declining. Indeed, in the 15 years between 1932 and 1948, the combined percentage content of nickel and copper mined in the Sudbury area dropped from just over 8% to 2%. With the increasing need to go underground or farther afield in order to increase (and in some cases even to maintain) output, the costs of exploration, development, and ore extraction and lifting in this country are likely to remain well above those esti-

[26]So far, recovery has been limited to nickel and some cobalt, but not as separate products. Consequently all of the iron and chromium and most of the cobalt, together with 20% to 25% of the nickel has been rejected, along with other tailings.

For the future, a considerably greater percentage recovery of cobalt must be assumed. This follows from the recent development by the Freeport Sulphur Company of a satisfactory process for recovering cobalt from their Moa Bay nickel ores. That company now has an agreement with the United States government to take all of their cobalt into the stockpile, if no other market can be found, at a price of $2. a pound. The extent of this output may be approximately 12,000 tons per year up to June 30, 1965.

[27]Besides the reserves of Cuba and New Caledonia, substantial nickel occurrences are known to exist in Brazil, the Celebes, the Philippine Islands, and Burma. However, inaccessibility and the lack of facilities and labour for operating them will probably prevent these areas from becoming more than minor sources of supply for some time to come.

mated for the extensive and well known lateritic deposits of Cuba and elsewhere. Canada's advantage, while it may not be a lasting one, therefore, remains at the processing and marketing levels. A continuing long-term upswing in demand, together with the various other external forces, including changes in public policy, which have in the past continued to stimulate the industry to even greater efforts, will still prevent it from lapsing into a state of mature contentment. Competition there will be on several fronts, particularly the technological. In meeting these challenges, the aggressive, scientific, engineering, and market research open to industry will stand it in good stead.

Table 8

ESTIMATED VOLUME OF PRODUCTION, TRADE AND CONSUMPTION OF NICKEL IN PRIMARY FORMS, CANADA, 1955, 1965 AND 1980

(volume in thousands of short tons)

Year	1955	1965	1980
Production	175	240	325
Exports	174	230	310
Consumption	4	10	15

(d) *Prospects for Further Processing*

Contrary to public opinion, a substantial quantity of Canadian nickel production is exported in the comparatively crude smelter concentrate or matte form. Between 35% and 40% is at present being shipped to Norway for the production of refined nickel, to the United States for the production of the nickel-copper alloy commonly referred to as "Monel" metal, and to the United Kingdom for the production of refined nickel, as well as for the isolation and refinement of most of the other lesser volume contained metal values. However, with the entry of new producers and the relative decline in the market for high nickel-copper alloys, the long-run tendency will be for an increase in the degree of primary processing at home.

Domestic market requirements are still so small (i.e., 2% to 3% of Canadian production) that even with an appreciable growth in the production of stainless steel and the non-ferrous nickel alloys, there will be little incentive from this direction. Custom smelting and refining of ores produced elsewhere also offers limited possibilities. Whereas, copper, lead, and zinc can be handled in this way, nickel is so diverse in its origin that each treatment facility has to be tailored pretty well to suit the characteristics of the ore which it is called upon to handle. The existing Canadian smelters and refineries can and do treat a comparatively small tonnage of sulphide ores on a custom basis. They cannot treat silicate or lateritic ores, however. Even were they to attempt it, the economics of transportation would, in most cases,

probably be against it. The latter materials, being found preponderantly in the Caribbean area, South America, Africa, and the Far East, and not being amenable to physical concentration, hence possessing a low unit value per ton, could only under exceptional circumstances be moved thousands of miles for treatment in this country.

The new hydro-metallurgical methods, such as the Forward process being used by Sherritt Gordon at Fort Saskatchewan, are even more specialized in their application. In this instance, pressure leaching has been developed specifically for the refinement of sulphide concentrates. It could not be applied directly to treatment of the lateritic ores such as those found in Cuba. Even the methods under consideration there vary as between deposits. Thus, it would appear that present technology, itself, would tend to militate against the construction of a smelter in Canada whose principal *raison d'être* was to be the custom treatment of a variety of ores from other parts of the world.

Over and above these raw material and processing considerations are others having to do with the location of markets and their ability to absorb by-products, the relative cheapness of various fuels and the availability of bulk chemicals. These considerations also make for the choice of one refinery location as against another. Ores of tropical origin, if they could be processed nearby or receive their initial treatment at adjoining centres in the United States, could, obviously, receive their early manufacture more economically there. Also ores and concentrates destined ultimately for sale in Western Europe may continue, based primarily on market considerations, to receive their early processing in France, Germany, the United Kingdom, and Norway.[28]

The domestic market being small and the prospects of custom smelting being limited, the prospects for expansion necessarily devolve upon the processing of a larger proportion of Canadian mining output prior to export.

This is an old and often vexatious question. Raised on numerous occasions prior to World War I and resisted at the time by the industry, the first production of refined metal in Canada was instituted at Port Colborne in 1918. Relying heavily on cheap electric power and subsequently proving to be quite economic, new smelting and refining capacities, along with improved methods and plant and equipment for concentration of the ore and the utilization in crude form of its numerous by-products, have been added more or less in line with the industry's level of output ever since.

[28]Within the last few years, four nickel refineries have been brought into operation: one in Canada (near Edmonton) ; two in the United States; and one large addition in Cuba. In addition, the Freeport Sulphur Co. is considering the erection of a refinery in New Orleans, to treat nickel slurry shipped from Cuba by tank steamer. A leaching plant, using bulk chemicals imported on the return run, is projected for the site of the ore at Moa Bay in Cuba.

The Falconbridge Company, when they started up in 1930, departed from this pattern by shipping their output of nickel-copper matte to a previously constructed refinery which they had purchased in Norway. Sherritt Gordon, taking advantage of newer chemical-metallurgical techniques, did the opposite when, in 1954, they began to rail-haul much of their output to Edmonton. There, all of the nickel concentrates produced at Lynn Lake are being reduced to metal by pressure leaching based on cheap natural gas.

As we have seen, substantial additions will be made to Canadian mine capacity over the next four or five years. Much of it, especially from Inco's Manitoba operations will be processed in Canada and, to this extent will modify the existing pattern of crude export versus primary manufacture in this country.

As for the longer term—influences appear to be at work in either direction. The ever growing need to treat lower grade ores and recover additional by-product values, the greater availability of natural gas as well as hydro-electricity across the country and the greater number of processes available for the treatment of nickel-bearing ores will all help to weight the scales in favour of a greater measure of manufacture in Canada. So will the fact that the United States tariff on everything up to and including refined metal has been considerably reduced.[29] On the other hand, the existence of considerable investments in plant and equipment, of know-how, and of an ever growing number of end-users will increase the pull of the market. Canada's advantage in terms of power costs has been largely whittled away. In certain applications, such as the production of alloy steel, a less highly manufactured product (nickel in oxide form) can be employed in any case. These considerations, while not necessarily overwhelming, will, no doubt, limit the amount of primary manufacturing done in this country.

As for the further manufacture of nickel alloys, in ingot and other forms, there will be even more definite limitations. Fabricated nickel products are still up against a serious tariff hurdle in entering the United States, the duties there ranging from 6¼% to 17½% on rolled, drawn and otherwise semi-fabricated nickel-containing items. The proximity to their markets of the alloying, fabricating, and nickel salts manufacturing establishments appears to be even more highly desirable from an industry point of view. Having made extensive investments in this connection, both in the United States and the United Kingdom, and facing similarly high tariffs in either country, the producers would be loath to redirect any sizable part of this programme to Canada.

[29]Since 1922, there has been no duty on nickel ore and matte. Nickel oxide was dutiable at 1¢ a pound from 1922 to 1930; duty free ever since. Under the Tariff Act of 1930, the United States import duty was 3¢ a pound on nickel metal. It was reduced to 2½¢ a pound as a result of the Canadian Trade Agreements in 1939 and was further reduced to 1¼¢ a pound during the General Agreements.

Table 9

ESTIMATED VOLUME OF PRODUCTION, TRADE AND CONSUMPTION OF NICKEL IN PRIMARY FORMS, CANADA, 1955, 1965 AND 1980

(value in constant 1955 dollars)

Year	1955 ($ million)	1965 ($ million)	1980 ($ million)
Production	216	300	400
Exports	215	285	390
Imports	3	5	8
Consumption	6	12	18

(e) *Corporate Structure of the Industry*

Discovered incidental to the search for iron ore in 1883, the Sudbury deposits were being worked by three companies as early as 1890. The Canadian Copper Co. (incorporated in Ohio in 1886) was, however, the only one to survive.[30]

During this early period, the industry was beset by two grave difficulties. The first was that of devising an economical method for treating these complex ores; the second was the limited market for nickel which, such as it was, was already controlled by the Rothechild's interest, S.A. Le Nickel, drawing on New Caledonia as their principal source of supply.

Such was the interest of United States and other defence authorities that, within a comparatively few years, two metallurgical extraction processes were developed. These were the Orford process, to which the Orford Copper Co. of New Jersey held the patent, and the Mond process, developed and perfected by Dr. Ludwig Mond and his associates in Great Britain. The former continued to be utilized, after 1902, by a consolidation of the already close interests of the Canadian Copper Co., the Orford Copper Co., and a number of other less important producers and distributors who were then merged into a single entity—the International Nickel Co. of New Jersey.

A few years prior to this, the Mond Nickel Co. had been incorporated in Great Britain. Subsequently, it acquired mines in the Sudbury area with which to service its smelter at Clydach in Wales. For more than a quarter of a century, these two companies, the International Nickel Co. and the Mond Nickel Co., dominated the scene in respect to both mining in Canada and marketing Canadian nickel throughout the world.

[30]The advent and course of the nickel industry has always been bound up with that of iron and steel. As a result of the early efforts to work the iron ore deposits of Hastings County, American interest turned northward. Organized as the Canadian Copper Co. in 1886, they purchased extensive holdings in the Sudbury area in the same year. Careful assays at that time revealed that, in addition to copper, the ore bodies over which they had control contained 3% to 4% nickel. Directly the company entered into a contract with another American firm—this one with smelting experience—the Orford Copper Co. Smelting of a low matte was commenced in 1888 at Copper Cliff, Ontario.

During the later stages of World War I, a new British government sponsored enterprise, the British American Nickel Corporation Ltd., also became active in this country. After securing mining properties in the Sudbury area, it began construction close by of a large smelting works and of a refinery near Duchesnes, Quebec. Employing exclusive rights in North America to the Hybinette electrolytic process for making refined metal and a competent staff of technicians, its mines and plants unfortunately came into production just at the time when the market for nickel was fast disappearing. Over-capitalized and unable to meet the drop both in volume and prices which characterized the early 1920's, British American Nickel went into liquidation in 1924. The assets of this company were subsequently acquired through an intermediary by the International Nickel and part of its process adopted, with modifications, for later use by that company.

The stronger position of Inco and Mond enabled them to weather the economic storm. Some years later, in 1929, they combined forces to form what is now known as International Nickel Co. of Canada, Ltd. This merger not only allowed the more efficient working of large deposits, which they held jointly in the Sudbury area, but provided for a new method of treating ore for which the Mond plant was not appropriate. It also brought within one organization all of the mines and smelters in Canada, the refineries in Canada and Great Britain, and the alloying plants, rolling mills and other fabricating and processing facilities which the two companies controlled on both sides of the Atlantic.

A new Canadian company—Falconbridge Nickel Mines Ltd.—also with properties in the Sudbury district, was incorporated in 1928. Its smelter there was blown in early in 1930. It has, however, exported its smelter product, except during World War II, to an electrolytic refinery which it then purchased and has subsequently expanded at Kristiansand, Norway. The possession of patent rights applicable only in Europe dictated this early decision.

Up until comparatively recently, only one large sulphide deposit has been opened up outside of Canada. In 1934, the Finnish government put up for auction a concession on a large nickel-bearing area near Petsamo which had been under exploration by Inco. This was secured by Mond Nickel, International's subsidiary in England, and was being developed for production during the late 1930's. This mine was taken out of Inco's hands in 1939 and eventually was seized from Finland by the Russians during World War II. The U.S.S.R. subsequently paid Inco $20 million by way of compensation.

In Canada, the industry, as we have seen, was long confined to a comparatively small area in Ontario. In 1941, however, a deposit of nickel-copper ore was found at Lynn Lake. In the late 1940's this was brought

under active development by Sherritt Gordon Mines Ltd. and proved capable of supporting production in volume over a considerable period of years. A railway has since been built to these deposits. Shipments over it of nickel and copper concentrates began in 1953. A refinery since built at Fort Saskatchewan, Alberta, now treats the nickel concentrates by an ammonia pressure leaching process. This latter facility was brought into operation in 1955.

As will be seen from the foregoing, the Canadian nickel industry now comprises three principal producers, two of whom are integrated up to and including the refining stage. The following table relating to the year 1954 gives some indication of the relative size, plant capacities, and current employment.

Table 10

COMPARISON OF THREE LEADING NICKEL PRODUCERS, CANADA, 1954

	International Nickel	Falcon-bridge	Sherritt Gordon
Percentage of total production	85	12	3[a]
Mines	5	5	2[b]
Smelters	2	1	—
Refineries	2[c]	1[d]	1[e]
Milling capacity in tons ore/day	42,000	4,800	2,000
Smelting capacity in terms of annual production in tons	150,000	41,500[f]	—
Annual refining capacity in tons	106,000	20,000	10,000
Rolling mills and secondary plants	4[g]	0	0
Employment in Canada[h]	17,593	2,860	828
Employment elsewhere	7,958	1,350	0

a Includes small percentage from two other small producers and other sources.
b Lynn Lake, Manitoba.
c Refineries at Port Colborne, Ontario and Clydach, Wales.
d Kristiansand, Norway.
e Fort Saskatchewan, Alberta.
f Nickel-Copper Bessemer matte.
g Two plants in the United States and two in Great Britain.
h Year 1954.

Table 11

PROVEN ORE RESERVES IN SHORT TONS, 1954

	Total	Nickel-copper content	Nickel production
International	261,619,000	7,875,000	142,500
Falconbridge	35,516,000	855,500	21,000
Sherritt Gordon	13,492,000	243,100	8,500
Total	310,627,000	8,973,600	172,000

Statistics relating to reserve holdings and annual rates of production reflect both the dominant position of International Nickel and the assured long-term supply position of all three of the major Canadian producers.

With respect to ownership and control, all three of these companies are predominantly owned and controlled outside of Canada.

Canadian participation in the common stock of International Nickel has varied over the years. In 1929, it was 29%; it fell to a low of 18% in 1946; presently it is in the order of 35%. United Kingdom holdings of voting stock now amounts to approximately 20%; that of United States citizens 43%.[31]

Sherritt Gordon Mines Ltd. was incorporated in Ontario in 1927. It formerly operated a copper mine at Sherridon, Manitoba. It is the most recent of the major entrants in the Canadian nickel-copper mining industry. Effective control of this company now rests in the United States. Evidence of this appears in the latest annual report of the Newmont Mining Corporation, incorporated in Delaware:

> "In view of the demonstrated success of the enterprise, and because the conversion privilege expires on June 30, 1956, your Corporation has notified Sherritt Gordon of its intention to convert into common stock the $8,000,000 principal amount of Sherritt Gordon's convertible debentures it now owns. This will result in the issuance to your Corporation of an additional 3,200,000 common shares, which added to the shares now held, will represent 38.3% ownership of the then outstanding stock of Sherritt Gordon."

In view of the widely held ownership pattern of the remaining shares of Sherritt Gordon, it is likely that more than 50% of the common stock is at present held by non-residents of Canada, principally corporations and individuals in the United States.

Falconbridge Nickel Mines Ltd. was incorporated in Ontario in 1928. Control of this company is held by Ventures Ltd. which owns 51% of the common shares. (In addition, shares are held by other companies in which Ventures Ltd. has an interest, e.g. Frobisher and Hoyle). Ventures Ltd., an Ontario corporation, is controlled by Canadian capital. The company's Norwegian refinery is operated by a wholly owned subsidiary of Falconbridge.

In conclusion, mention should be made of a number of other relatively small companies and other sources presently under active development in Canada. In the Sudbury district are two additional small operators, namely Nickel Rim Mines Ltd. with an 800-ton capacity mill and Nickel Offsets Ltd. with a 300-ton mill. Both ship their concentrates to the Falconbridge smelter. Deloro Smelting and Refining Co. Ltd., located at Deloro, Ontario, recovers some nickel in the form of oxides and salts in the processing of cobalt. Yet another company, known as the Eastern Mining and Smelting Corporation Ltd. is well advanced in its plan to construct a small custom smelter at Chicoutimi, Quebec.

[31]As of May, 1957, the percentage of shares held was: Canada, 34%, U.S., 43.1% and United Kingdom and others, 22%. The percentage of shareholders by number was: Canada, 51.2%, U.S., 42.9% and U.K. and others, 5.9%.

(f) *Financing and Development*

The recent rise of Falconbridge Nickel Mines Ltd. to the position of a major producer came as a result of an aggressive exploratory programme which opened up the northern nickel range of the Sudbury basin and from substantial contracts which that company subsequently obtained from the United States government. Under an agreement with the United States Defense Materials Procurement Agency, signed in 1953, Falconbridge was assured of a market for 75,000 tons of nickel in addition to other contracts made earlier for 37,000 tons. With this guaranteed market, it was then possible for Falconbridge to secure the necessary funds to carry out a sizable expansion programme.

Other nickel producers have similarly been encouraged by the Defense Materials Procurement Agency, e.g., International Nickel in 1954, and some of the very much smaller producers, such as Nickel Rim Mines and Nickel Offsets Ltd.

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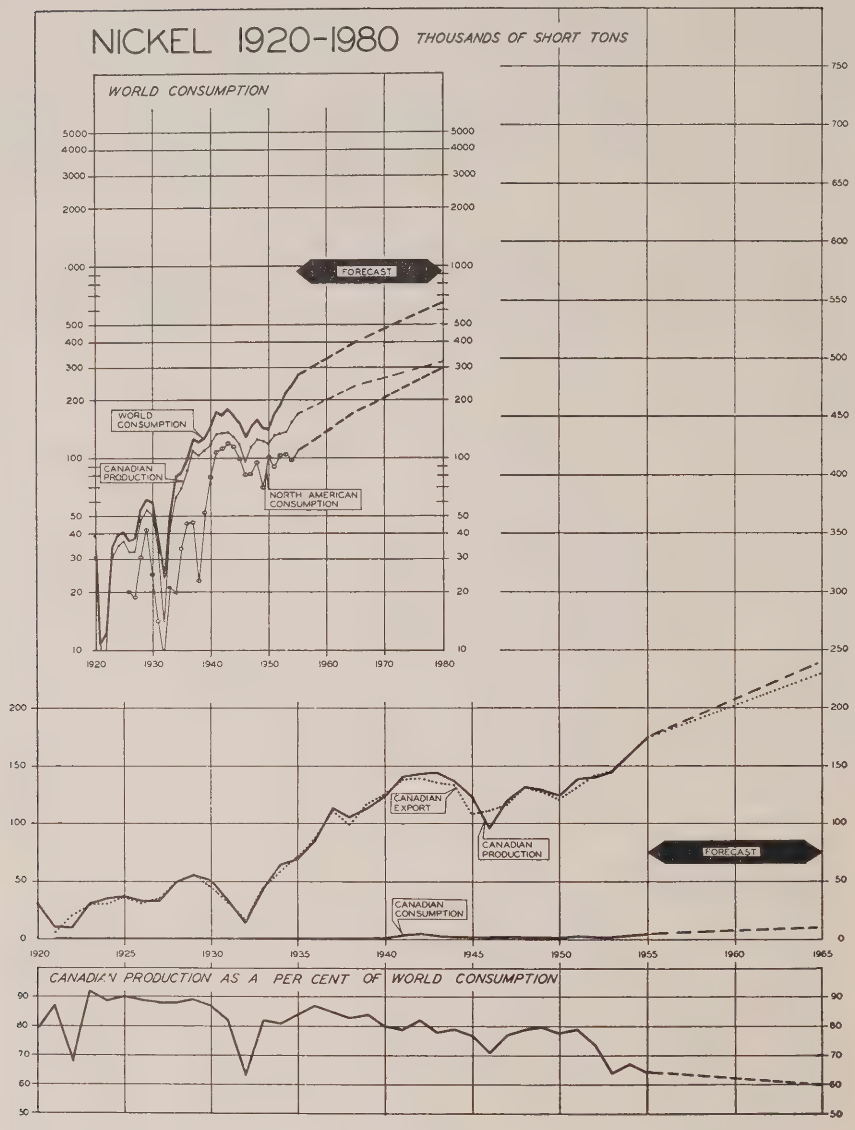

NICKEL 1920-1980
THOUSANDS OF SHORT TONS
WORLD CONSUMPTION
FORECAST
WORLD CONSUMPTION
CANADIAN PRODUCTION
NORTH AMERICAN CONSUMPTION
CANADIAN EXPORT
CANADIAN PRODUCTION
FORECAST
CANADIAN CONSUMPTION
CANADIAN PRODUCTION AS A PER CENT OF WORLD CONSUMPTION

D. Copper

(a) *General Introduction*

The leadership of copper, for centuries the most important of the non-ferrous metals, is being challenged. It has been giving way to aluminum in a number of applications. Occasionally its place is being taken by steel and other alloys. To some extent, plastics are also being used in lieu of copper, either because the latter has been in short supply or because its price has periodically been out of line with the value which industrial designers and architects have placed upon it.

Nevertheless, in absolute terms, copper consumption is continuing to increase. Recovering year by year since the end of World War II, it is again approaching the all-time high reported in 1943. Available industry forecasts suggest that world demand will continue to increase at about the same long-term rate that has been experienced since the mid-1920's. Rising by more than 2% a year, consumption might exceed four million tons annually by 1965.

Supporting this trend is the growth of a number of copper-using industries which are expanding at a rate well above that of most other areas of economic activity. An outstanding example is the electric power utilities. As copper is essential in the generation, transmission and distribution of electricity, a world growth rate for power consumption in the vicinity of 7% per annum is bound to have important consequences in the market for copper. In like manner, additional quantities of metal are also being consumed in the production of certain types of industrial machinery, of consumer durables, of equipment for the communications industry and as pipe and tubing in construction.

Historically, the United States has played a dominant role in the market for copper. For a long time she was the world's leading producer, but recently her mines have proved incapable of meeting the required substantial increase in demand. In need of rehabilitation after the effort of World War II, copper has also been slow in developing new capacity elsewhere. Strikes in the United States, in Chile and in Northern Rhodesia, together with the diversion of substantial quantities of metal for stockpiling purposes in the United States, have therefore resulted in periodic shortages. The price of copper, while generally trending upward, has moved sharply first in one direction and then in another. Only now are the results of the heavy investments which were made in new mine capacity during the postwar period beginning to have a significant effect upon the over-all supply situation.

Given a favourable long-term market outlook, considerable resources and the insurance against the effect of extreme copper market fluctuations provided by the tri-metal content of most domestic ores, the Canadian copper mining industry is flourishing as never before. The existing producers

are expanding their output. Old properties are being re-examined and new mines, the result of an intensive programme of exploration and development, are being established. As a consequence of these activities, the total value of Canadian primary production exceeded $290 million in 1956.

Partly because it enjoys a substantial domestic market, partly because of its favourable reserve and cost position and partly because of the increasing gap between primary production and consumption in the United States, the copper mining industry in Canada appears to be assured of an expanding future.

(b) *Fluctuations in the Copper Market*

One of the more notable characteristics of the copper market has been its comparative instability. Copper prices have veered sharply upward or downward, changing direction abruptly within a comparatively few months. Consumption, meanwhile, has followed a more orderly course. Over the long run, both North American and world requirements have tended to move steadily upward.

Since the beginning of this century, the world copper market has passed through three distinct phases; the period 1900 to 1929, that from 1930 to 1935 and that from 1946 to the present. During the first of these periods, mine output roughly quadrupled, rising from approximately 500,000 tons in 1900 to more than two million short tons in 1929. Up until 1914, consumption expanded more or less in step with production and hence the price of copper remained comparatively stable. The industrial consequences of World War I, by further stimulating demand, seriously disturbed that balance. It was followed within a period of years by remarkable improvements in mining and refining methods and by a consequent reduction in costs. Through the 1920's, therefore, prices began to move within much wider limits. American producers (who still dominated world markets) attempted to control this situation by forming an international marketing agency, The Copper Exporters Inc. With roughly all the world's supplies within their control, they managed nearly to double the price of copper between 1926 and 1929. However, with the onset of the Depression and the resulting stresses which it generated, this producers' alliance broke down.

Copper then fell from better than 24¢ to less than 5¢ a pound, an all-time low. But even greater difficulties were in train. The second market phase beginning in the 1930's was characterized at the outset by extraordinary new developments which greatly altered the status of the United States in the world's copper economy.

The younger producing countries, namely the Belgian Congo, Northern Rhodesia, Chile and Canada, had among them produced less than 400,000 tons of copper in 1925, the year in which the copper cartel was negotiated.

By 1938, utilizing only about 80% of their actual capacity, the combined output of these newcomer nations had advanced to well over one million tons. Meanwhile, the total of world production was about the same as that achieved in 1929, around two million tons. Practically all of this new metal produced in the copper fields of central Africa, Canada and Chile was being extracted from comparatively low-cost mines, and their rise to prominence naturally found its reflection in prices; copper remained a comparatively cheap metal through the late 1930's and well into World War II.

The virtual abdication of the United States copper producers as unchallenged leaders in the world market was due in part to higher costs at home. True, they maintained a dominant financial interest in Chile and certain other foreign countries, but the costs of new metal sources in the United States were now well out of line with those encountered elsewhere. As a result of their pleadings, the United States government introduced a prohibitive copper duty of 4¢ a pound in 1932 (about 80% of the contemporary market price). This effectively isolated the United States market from that of the rest of the world. Yet, despite its favoured position, United States copper production fell sharply. By the time World War II began in 1939, the United States had moved from the position of a major exporter of copper to one of bare self-sufficiency.

The American tariff increase of 1932 forced the new expanding copper industries in Africa, in South America and in Canada to develop markets elsewhere. Over-all consumption recovered substantially from the depression low of the early 1930's, yet its growth was hampered by both continued business difficulties and economic nationalism. As early as 1935 the Belgian Congo, Rhodesia, Chile and Mexico attempted to restrict copper surpluses from reaching the market. The fact that they were not successful, together with the industry's other difficulties, helps to explain the recurrent fear among copper experts, who were concerned with marketing in the 1930's, that limitations in output are necessary if the present relatively high price for new metal is to be maintained.

World War II did not materially change the basic position of the copper industry. In contrast to World War I, prices were strictly controlled between 1939 and 1945. Moreover (in marked contrast to the rubber and tin producing industries) the world's copper mining areas did not suffer destruction. Hostilities during World War II did not spread to the source areas themselves. What the war did, however, was to put to the test the new resources developed between 1925 and 1939. As a result of unparalleled demand, world output rapidly approached capacity levels. In 1942 it achieved the hitherto unequalled figure of about three million short tons.

With peace, the copper industry entered its third distinct phase since 1900. Full employment became a universal objective, and in its attainment the

leading copper consuming industries—the electrical utilities, transport, communications and construction—had an important role to play. Civilian demand, which in the 1930's had limped behind the growth in copper production, expanded by leaps and bounds. Over and above this were current defence production and United States strategic stockpile requirements.

Though the postwar resurgence in consumption has been worldwide, it has also been influenced by the reintegration of the United States into the world market; this time, however, as a large-scale importer and not, as before 1939, a major exporter of new metal. In recent years, that country's net imports have ranged from 350,000 to well over 500,000 short tons a year. It was with the conviction that this was no mere passing phase that the United States negotiators at the GATT discussions in 1947 permitted the 1932 tariff to be cut in half (i.e. to 2¢ per pound). Actually the application of any tariff whatsoever has been suspended—a situation which, short of a drastic fall in price, may persist for many years to come.

As early as 1946, it had become obvious that world requirements of copper would, within a short time, surpass the productive resources developed between 1925 and 1939, and that additional resources would have to be developed to allow production to keep pace with demand. Unfortunately, the impact of state trading and the closing of the international copper exchanges—which continued in the United Kingdom until August, 1953—deprived the copper industry of a much needed sensitive barometer. For far too long, therefore, the full implications of the postwar changes remained hidden. Relying on interwar experience, traders, consumers and even the majority of producers were constantly expecting a slump just around the corner. With this attitude prevailing, and with mounting difficulties from the high cost of equipment, interference by governments in the producing countries and growing labour problems, it was not surprising that the development of new resources fell behind.

The boom following the outbreak of war in Korea confronted the world for the first time with the fact that the growth in copper demand in the first five years after World War II had done more than simply absorb the excess of new resources developed before the War. This fact was very much emphasized (and, for most Commonwealth producers, also driven home) by the studies of the International Materials Conference between 1951 and 1953.

But although the authors of the Paley Commission Report went even further and projected supply problems as far ahead as 1975, little could be done immediately to create new mine capacity on a really large scale. An unfortunate wave of strikes in Chile, Rhodesia and the United States therefore set the stage for further price increases, culminating in an all-time United States high quotation of 46¢ a pound early in 1956.

While short-run dislocations were an immediate cause, the problem was a more intractable one. Consumption, by continuing to mount, clearly outpaced the industry's short-term ability to produce ore. Over the previous 15 years a large surplus gave way to a bare balance between supply and demand which any loss of production would have quickly transformed into an open deficit. In mid-1956, however, the world supply of copper became adequate to meet the demand, and price declined a few cents at a time, down to 31¢ in May, 1957.

Any assessment of current price prospects on the basis of past experience must be misleading, especially since in the nature of the market place, marginal deficiencies have a very pronounced impact on prices. The fact, therefore, that recent market prices have been between two and three times as high as the average cost at which more than 80% of the world's copper is being produced, should not be taken as an indicator that the copper market is in the grip of a unique and essentially short-term dislocation.

(c) Long-Run Consumption Trends

Copper has gained wide acceptance because of its unique physical and chemical properties. It is an excellent conductor of electricity and heat, it is resistent to corrosion and, because it can be combined readily with many other metals, it yields strong yet malleable and ductile alloys. About half of the world's copper production is consumed in relatively pure form by the electrical industry, entering extensively into the manufacture of generators and motors, switch gear and power line, telephone and telegraph equipment. Much of the remainder is alloyed with zinc, nickel, lead and tin. Frequently employed in the form of tubing, pipe and sheet it is used extensively in shipbuilding, in the production of machine tools, automotive, railroad, refrigeration, air conditioning and other equipment, and in plumbing and construction supplies. Its natural beauty also suits it to purely architectural and other decorative uses.

Most of the industries which copper serves are growing rapidly. This is particularly true of electric power. New construction, both of the manufacturing and residential or commercial type, has also placed a premium on copper. Thus, substitution by other materials—and particularly by aluminum—has served only to moderate, not to curtail, the long-run upward trend in consumption of this large tonnage metal.

Over the past 30 years, world figures reflect a near doubling in the amount of copper used. This is equivalent to between a 2.5% and a 3% average annual increase in demand. It is a rate of growth, furthermore, which has been maintained in recent years despite continued shortages, a high price for copper and priorities in defence applications—each of which has provided its own incentive to further substitution. It is reasonable to assume that, had

additional mine production been available, the upward trend in consumption would have been even more impressive.

The market for copper provides evidence both of strength and weakness. Demand is continuing strong in the majority of electrical applications calling for copper in the form of rod and wire. Copper pipe and tubing for plumbing and other construction purposes are being sold in ever increasing volume. Trending downward, on the other hand, is the amount of new metal used in the manufacture of alloys, particularly the brasses and bronzes. Chemical applications have also shown a tendency to fall off since the end of World War II. Otherwise, and this generalization covers a host of other end uses, consumption appears to be continuing with little change from one year to the next.[32]

Another factor influencing the demand for new production is the supply of secondary or scrap metal. Over the long run, any limitations would put an increasing emphasis upon the need to discover additional resources. In the late 1920's, scrap accounted for nearly 40% of all the copper entering the North American supply stream and this proportion still remains fairly constant. There has, however, been a relative decline in alloy production, from which source about 75% of all secondary metal is still recovered. This, with the progressive orientation of demand toward the more permanent or dissipative uses of copper, could mean that by the end of perhaps another quarter century, new mine production (as opposed to secondary recovery from scrap) may be called upon to meet an even greater proportion of the world's needs.

Substitution, meanwhile, will continue. The electrical industry, for one, will continue to look to aluminum. Aluminum wire with a steel core has already displaced copper for long distance transmission. Other typical substitutions are taking place in fractional horsepower motor windings and light bulb bases. On the munitions front, a major move away from brass to steel for large shell cases has taken place. Titanium, as its price falls, may also replace copper in certain uses where a premium is paid for corrosion resistance. Iron, in the shape of stainless steel or in other forms, has much to recommend it in new construction, while the use of aluminum in the building trades is progressing by leaps and bounds. Clad metals, including copper-clad iron, are finding favour among architects and designers. Should their use become more general, this should also result in a substantial diversion of copper to other and more remunerative applications.

Printed electrical circuits are also slightly reducing copper wire requirements for communications and electronic equipment. Recent market studies show up something else: that if copper is not being replaced neither is it

[32]Over 50% of all copper currently consumed in North America is being used by the electric power utilities and manufacturers of electrical apparatus and supplies. Some 15% is going into building materials and construction; about 13% into machinery and equipment and about 12% into motor vehicles.

being incorporated into new goods as rapidly as other materials, e.g. aluminum. For example, the United States Department of Commerce recently issued an analysis of consumption of copper vs. consumption of aluminum. In 25 selected industries, including electrical appliances, the total use of copper base products increased by only 1.6% between 1947 and 1954. In the same period, the use of aluminum in these industries increased by 66.35% and represented about one-third the consumption of copper in these industries at the end of the period.

Other statistics[33] comparing growth in the over-all use of aluminum with growth in the over-all use of copper are:

	Aluminum	*Copper*
Percentage growth in U.S. since 1950	198	107
Percentage growth in world total since 1950	208	135

Adjustments of this kind imply a continuing shift in the over-all pattern of copper consumption. Rarely, however, will they mean total elimination in use. Instead, they will make more copper available for those applications to which its properties are particularly well suited. A determined effort to produce an automobile radiator from something other than copper, for example, has so far been unsuccessful. The heating, plumbing, air conditioning and refrigeration industries do not expect copper to be substantially replaced in their fields. The electrical industry too has many applications in which copper must be retained because of its unique characteristics. Since the use of electricity itself is increasing at a compound rate of 7% per annum, the world's copper producers could hardly expect to supply more than a portion of the demands originating in this already dominant market sector.

Regional considerations must not be discounted. World War II and its aftermath served first to depress and, subsequently, to retard the use of copper abroad. Because of this, consumption in many countries in Western Europe has only recently begun to exceed that of the late 1930's. North America, by contrast, has maintained its usage at close to its World War II peak. As European and other regional requirements begin again to approximate those of the United States, any slack which develops on this continent may well be taken up by expanding markets elsewhere.

Outside Europe, the demand for copper may be even more insistent. Over the past half century, consumers in North America, comprising less than 8% of the world's population, have absorbed more than 40% of the world's copper. Since 1945 the United States alone has consumed more than 45%. What will happen as the remaining 92% of the world's population becomes more conscious of electric power and other equipment is difficult to anticipate. Assuming reasonably peaceful conditions for development, a pro-

[33]From American Bureau of Metal Statistics for 1956 (issued January 1957).

jection of the long-run upward course in copper consumption would certainly seem probable.

Table 12

INDUSTRIAL CONSUMPTION OF COPPER IN VARIOUS COUNTRIES

(thousands of short tons)

	Average 1935-39	1955
United States	757	1,446
Western Europe	690	1,350
U.S.S.R.	172	375
Canada	55	139
Latin America	10	78
South Africa	5	20
India	10	24

The forecast in this report, while it envisages some slowing down in demand, is conditioned much more by supply considerations. Shortages, though less persistent than in recent years, will keep the price of copper up and thereby encourage further substitution. Were mine production to permit a reasonable balance between supply and demand, consumption might well continue to increase at its long-run average rate. Failure to keep up with the market opportunities which might otherwise present themselves would inevitably mean a lower consumption rate. Based on the expectation that additional supplies of copper will be forthcoming, and that their timing will be such as to maintain its average price at or below 35¢ a pound, world consumption is seen as rising from 3½ million short tons in 1955 to over 5 million tons in 1980; that is to say, at an average rate of just over 2% per annum.

Forecasts of demand, whether national, regional or related to the world as a whole, are necessarily conditioned by assumptions as to price. Data recently compiled for the United States, covering the years from 1913 to 1954, reveal a close and continuing relationship between the level of industrial activity and the value of new copper sold for industrial purposes.[34] The United States Index of Industrial Production (Federal Reserve Board) multiplied by the index of wholesale prices was plotted alongside the volume of copper entering industrial usage multiplied by the average annual price of copper. The two curves followed each other quite closely throughout the entire 40-year period. This suggests that a pronounced rise in the real price (i.e. relative to other commodities) of copper will result in a commensurate fall in its usage. We are here forecasting an appreciable (10% to 25%) rise in real price over the period between now and 1980. This is consistent—at least if United States experience is any guide—with a fall from a 2.5% annual increase in world demand to one of 2%.

[34]See W. P. Shea, "The Price of Copper, 1955-1975", *Engineering and Mining Journal*, Vol. 156, August, 1955.

(d) World Reserve and Production Prospects

Copper, as we have seen, will be required in increasing volume. Inadequate supplies did, for a time at least, ensure a relatively high price level. Although this has fallen sharply, the incentive is still there to create additional capacity. Operations in existing mines will be expanded. New discoveries will be made and some of the world's already known but more remote properties will be opened up. Though it may be some time before all these plans are realized, an appreciable increase in world mine output appears to be in prospect.

A brief review of the world's supply position is interesting in this connection. Copper, though it occurs widely in nature, is produced essentially in five major regions—the western United States, south-central Africa, Chile, central Canada and Kazakhstan in the U.S.S.R. Known resources in these areas constitute about 90% of the world's proven copper reserves. In total, they amount to between 100 million and 200 million tons of copper. This is a quantity sufficient to support the present world level of output for something like 50 years.[35]

The situation, as one might expect, varies considerably from one region or country to the next. The United States, though still the world's largest producer, has only something like 25 years of proven supplies on hand. The grade of the ore being worked in American mines too has been falling for many years. From a copper content of around 1.7% in the early 1920's, it now ranges between 0.8% and 0.9%. Elsewhere, and particularly in Northern Rhodesia, reserves of 3% to 6% ore exist in quantities which could be worked for as long as 100 years. The Chilean deposits include huge tonnage averaging better than 2% copper. Canadian ore, by contrast, works out at around 1.5%. Such information as is available on the Russian deposits suggests that they have a copper content comparable to those being worked in the United States.

Various factors, in addition to presently proven reserves and grades of ore must, however, be taken into account. A high, and possibly increasing, price level will help to render more ore of commercial value. Improvements in technology and mechanization made possible by operating continuously and on a large scale can have a similar effect. United States mine output has averaged better than 950,000 tons of copper a year during the quarter century which followed World War I. It is presently in the order of over one million tons annually and may exceed 1,250,000 tons a year between now and 1961. Thus the declining grade of ore mined in the United States has not merely reflected the exhaustion of richer reserves but is due partly to the

[35]The following quotation appears in the U.S. Bureau of Mines, Bulletin 556, "Copper", a chapter from *Mineral Facts and Problems,* Washington, 1956. "Most observers agree that world copper reserves exceed 100 million short tons of recoverable metal with the prospect that, when conditions for production in foreign countries improve (that is, when adequate power, transportation and other facilities are supplied, and political, labour and other problems alleviated or solved), reserves may be double the quantity given."

ability of the industry to exploit lower-grade material at a profit. Developments of this kind, given political stability and long-term market contracts may, and indeed are, taking place in other parts of the world.

Three-fourths of American production comes from large-scale, low-cost, open-pit deposits. This is in marked contrast to the predominance of underground mines in South America, Africa and Canada. However, the United States open-pit operations face eventual termination because of the increasingly adverse ratios of waste rock to minable copper ore.

The supply of copper known to be recoverable in the United States at present prices is in the vicinity of 25 million tons of new metal. Assuming present rates of production, their larger producing mines have a 20-year life expectancy; in exceptional cases, 30 years. The producibility of these properties may, however, be extended if further developments in mining techniques permit an eventual changeover from open-pit to underground mining. Exploration campaigns over the past decade have turned up an additional 10 to 15 years of supply. Their existence, in other words, is being perpetuated by exploration, development, improvements in mining techniques and the workings of the market. Though resort may have to be had to the treatment of even lower-grade material, it is believed that a one million ton a year level of copper output can be maintained until at least 1980.

The struggle to maintain the United States reserve position is interesting on two counts. To the extent that it falls short of consumption, additional imports will be required. Also, it is bound to yield additional knowledge, and to encourage the development of mining machinery and equipment which can be turned to advantage elsewhere. Brought to bear in such situations as characterize mining in Northern Rhodesia, Uganda, the Belgian Congo, Chile and Peru, they will further tend to reduce, or at least to stabilize, costs. There is a body of expert opinion which holds that 90% or more of the 1955 world output of approximately 3.4 million tons could be mined profitably at a price of around 25¢ a pound. Costs after taxes in 1954 have been reported to be in the order of 22¢ in Chile and 21.5¢ in Rhodesia. Compared to the average price of copper in 1955 of around 37¢ per pound, this suggests a considerable margin for expansion into ore which had been considered too low in grade to permit profitable operation.

As is now known, considerable additions will be made to existing mine capacity over the next four or five years. United States production, stimulated by government support measures, may increase by a further 10%. United States funds have also been placed at the disposal of a number of foreign development projects. Costing in excess of $100 million, they range from the extensive Toquetala scheme in Peru to the small Akjoujt deposit in French Mauretania.

In order to give a sense of proportion, it may be useful to list the major producing countries in order of their current volume of output. In 1955, mines in the United States produced approximately 1,014,000 tons of copper. Chile was in second place with 477,000 tons, followed by Northern Rhodesia with 395,000 tons. Output in the U.S.S.R. in 1955 was believed to be in the order of 372,000 tons and in Canada 325,000 tons. Mines in the Belgian Congo in that year turned out some 259,000 tons of copper. Other producing countries of note were Japan and the neighbouring peninsula of Korea (80,000 tons), Mexico (60,000 tons), Peru (48,000 tons), the Union of South Africa (47,000 tons), Australia (44,000 tons), and Yugoslavia (32,000 tons).

Over the next few years considerable additions will be made to existing capacities. Plans are already well advanced for increased mine production and mineral smelter and refinery output in most of the world's major copper-producing regions. The recent discoveries are expected to make a significant contribution. The bulk of the additional metal which will be produced between now and 1960 will continue to come from deposits in and around the existing operations.

In the United States, additional stimulus is being provided by the Defense Production Act; that is, through government loans, government purchase contracts and tax-amortization benefits, or combinations of the three. In total, projects costing close to $200 million should add approximately 10% to United States copper mine output over the next three or four years. All the major producers are involved, including the Anaconda Copper Mining Company, the American Smelting and Refining Company, the Phelps Dodge Corporation and the Kennecott Copper Corporation. As a result of these activities, additional material ranging from 0.8% to 1.0% copper content will be worked in Montana, Nevada, Arizona and Michigan.

Elsewhere costs are likely to be lower than the investment of $1,500 to $2,000 per ton of capacity which is required to bring in additional plant in the United States. In a number of instances, United States government stockpile or other contracts are also becoming effective. With financing assured, and with the likelihood that the commercial market for copper will remain strong, further announcements of increased capacity abroad are to be expected.

In Northern Rhodesia, several projects capable of producing an additional 100,000 tons of copper a year have been launched. Two involve the production of cobalt as a by-product; one is to work 5.2% copper, while the other averages 3.6% copper. In Uganda, cobalt values also help to improve the economics of the mining operations.

Additional capacity is also being introduced in the Belgian Congo, Chile and Peru. Perhaps another 200,000 tons of annual output may be added in

this way. The Peru workings are of particular interest in that they involve the exploitation of extensive porphyry-type copper deposits similar to those mined at Butte in Montana. The grade is around 1%, and production can be expanded rapidly, using mining and processing techniques similar to those already in use in the western United States.

Though activity is being stepped up elsewhere, details are lacking. Undoubtedly, output will rise in Yugoslavia and the U.S.S.R., and in Canada. All told, these developments, including those in Canada, may make possible a level of world production in the order of 3.8 million tons in 1960—up, that is, by approximately 400,000 tons from the 3.4 million tons mined in 1955.

With the results of these efforts in mind, a figure of five million short tons for 1980 appears to be attainable. However, this presumes considerable additions to mine capacity outside of North America. Also, it presumes that the United States becomes a substantial importer of new copper from expanded properties in South America, Canada and possibly south and central Africa as well.

(e) Canadian Production Prospects

The question now arises as to how Canada compares with other copper-producing regions in the world. With the exception of the large nickel-copper deposits in the Sudbury area, this country does not possess developed deposits comparable in size with those now being worked in the western United States, Africa and South America. Neither have many extensive bodies of low-grade or near-marginal ore been found which might be considered as potential resources for the future. Though numerous developments have taken place, particularly since 1950, better than 45% of the nation's mine output still originates in the Sudbury district. Another 30% comes from the Noranda gold mining area. Much of the remainder is produced in western Canada from properties which were being worked in the early 1930's.

The minerals of Canadian copper deposits are essentially sulphides and are found in three of the nation's principal geological regions, the Precambrian, the Cordilleran and the Appalachian. This widespread distribution has resulted in copper mining activity extending from Newfoundland to British Columbia. The vast extent of the area which remains to be prospected offers exceptional possibilities for the future discovery of copper and other copper-bearing mineral deposits.

A significant characteristic of the Canadian copper ores is their bi-metal and sometimes tri-metal composition. Deposits may be copper-nickel, copper-gold, copper-zinc and, in a few cases, copper-lead-zinc in combination. There are comparatively few mines in Canada that can be classed essentially as copper mines in the same sense as those in the United States and elsewhere. This feature has had an important influence on both the economics

and technology of non-ferrous metal development in this country. Ores with a copper content too low to be mined as such have been worked profitably, and are continuing to be worked, because of their gold, nickel or base metal content.

While production from existing mines is scheduled to increase, new discoveries and redevelopments also promise to add substantially to the nation's productive capacity. In Newfoundland, the old Tilt Cove Mine is being reopened. Several large developments with copper as a major by-product are in progress in New Brunswick. The Chibougamau district in Quebec, with several mines in production and other developments in progress, is fast becoming an important Canadian copper producing region. At Manitouwadge, Ontario, immediately north of Lake Superior, another promising camp is emerging. Some copper may be produced along with nickel from the Mystery and Moak Lake areas of Manitoba. Out on the west coast, the Granduc mines north of Stewart will help to regain for British Columbia a position among the front ranks of Canada's copper producing provinces.

All told, including by-product copper from operations designed primarily to recover other metals, plans now afoot indicate a potential Canadian mine capacity in the vicinity of 420,000 tons in 1960. This is up substantially from the 356,000-ton figure reported for 1956. Other developments will doubtless follow. More copper will probably be produced from new mines in northern and eastern Quebec, New Brunswick and Manitoba. Possibilities of considerable interest also exist in northern and southwestern British Columbia, Yukon and the Northwest Territories. For this reason, and because vast areas favourable for prospecting still await exploration, an annual output in excess of 500,000 tons in 1980 does not appear impossible.

With continuation of the present price level, and the preference of investors for exploring and developing new producing capabilities within rather than outside the continent, one can envisage a steady increase in production extending on through 1965 and possibly beyond 1970. Thereafter, new discoveries may be largely offset by the progressive exhaustion and abandonment of some of the properties in production today. Viewed in its longer-term perspective, we may therefore see the Canadian copper mining industry repeating its remarkable performance of the 1930's and increasing its output of new metal by better than 50% over the next quarter century.

Markets, of course, must be available. In this respect, Canadian produced copper has an advantage over many of the other metals mined in this country. Over one-third, and sometimes better than 40%, of Canada's output has been consumed at home. Domestic requirements which were modest during the interwar period even exceeded exports for a time during World War II. Since 1945 consumption in this country has edged slowly upward, although exports, too, have again risen to the point where they exceed the tonnage

retained in Canada by a ratio of about 2 to 1. The United States and the United Kingdom are currently purchasing almost identical quantities. While the United States provided Canada's main export market during the 1920's, the United Kingdom bought more Canadian metal during the 1930's, World War II and the immediate postwar period. Other countries continue to take comparatively modest amounts either in the form of ores and concentrates or as refined metal.

Future developments on the demand side are difficult to assess except in aggregate. Canadian requirements, now in the order of 140,000 tons a year, might well exceed 200,000 tons and possibly be in the order of 250,000 tons in 1980. The United States, with an import requirement of around one million tons a year, may take several hundred thousand tons from Canada 25 years hence. On the other hand, non-dollar countries, including the United Kingdom, may obtain a greater proportion of their requirements from Africa and elsewhere. Yet, even under these circumstances, sales covering both Canadian requirements and export commitments of better than 500,000 short tons in 1980 does not appear to be out of line with the predictions expressed by experts in the industry and with the various forecasts described elsewhere in this study.

Were these expectations to be realized, Canadian producers would gain a somewhat larger share of the world's copper market. In the early 1930's, they mined approximately 10% of world consumption. By 1953, because of the exceptional inroads made on Canadian capacity by World War II, the proportion had fallen to 8%. Currently it is better than 9%. Our forecast of Canadian production, when viewed against the long-run consumption trends advanced earlier in this chapter, points toward an approximate 10% relationship between Canadian and world output 25 years hence.

The following table summarizes the estimates of production, exports and consumption which are also shown graphically in the chart entitled Copper, 1920-1980.

Table 13

CANADIAN PRODUCTION, CONSUMPTION AND EXPORTS OF COPPER, 1955-80

(in thousands of short tons)

Year	Canadian production	Domestic consumption	Exports U.S.	Exports Overseas	Exports Total
1955	325	139	94	101	195
1965	450	165	160	125	285
1980	550	225[a]	200	125	325
	(500-600)	(200-250)	—	—	(300-350)

[a] Assuming a 2% per annum rate of increase in Canadian consumption.

(f) Structure of the Canadian Industry

The largest Canadian producers are partially or wholly integrated; that is to say, they engage not only in mining but also in primary processing. One, Noranda, includes fabricating activities as well. They are also preponderantly foreign owned. With the exception of Noranda Mines Limited, Falconbridge and some of the smaller and more recent Canadian copper producers, control lies essentially in the United States. There is also a certain amount of United Kingdom participation.

The largest producers of the integrated type are the International Nickel Co. of Canada Limited (42% of Canadian production), Noranda Mines Limited (28%) and the Hudson Bay Mining and Smelting Co. Ltd. (15%). Together these three accounted for all but 15% of the nation's copper output in 1955. The following tabulation, which is more complete, also indicates relative size as measured in terms of daily capacity and the geographical location of the larger Canadian mines.

Table 14

LARGER CANADIAN COPPER SOURCES

Mines	District	Type of ore	Milling capacity tons–day
Newfoundland			
Buchans	Red Indian Lake	Zn-Pb-Cu	1,300
Quebec			
Gaspé Copper	Gaspé	Cu	6,500
Noranda	Rouyn-Noranda	Cu-Au	3,000
Quemont	"	Cu-Zn	2,000
East Sullivan	"	Cu-Zn	2,000
Waite Amulet	"	Cu-Zn	1,800
Campbell Chibougamau	Chibougamau	Cu-Au	1,700
Normetal	Abitibi	Cu-Zn	1,000
Quebec Copper	Eastern townships	Cu	700
Opemiska	Chibougamau	Cu-Au	800
Weedon	Eastern townships	Cu-Zn	300
Ontario			
International Nickel[a]	Sudbury	Cu-Ni	42,000
Falconbridge[b]	"	Cu-Ni	4,800
Nickel Rim	"	Cu-Ni	800
Manitoba-Saskatchewan			
Flin Flon (Hudson Bay)[c]	Flin Flon	Cu-Zn	6,000
Manitoba			
Lynn Lake (Sherritt Gordon)	Lynn Lake	Cu-Ni	2,000
British Columbia			
Britannia	Britannia Beach	Cu-Zn	6,500

a Includes five operating mines.
b Includes five operating mines.
c Includes four operating mines.

In addition to the mines there are six primary copper smelters in this country, three of which are of conventional type. The remainder treat copper-nickel ores and are adapted to handle metal produced in the Sudbury basin. Their location and capacity are also reported for the year 1955.

Table 15

COPPER SMELTERS, LOCATION AND CAPACITY, 1955

Company	Location	Annual capacity in tons
The International Nickel Co. of Canada	Copper Cliff, Ont.	168,000
The International Nickel Co. of Canada	Coniston, Ont.	
Noranda Mines Ltd.	Noranda, Que.	85,000
Hudson Bay Mining and Smelting Co. Ltd.	Flin Flon, Man.	45,000
Falconbridge Nickel Mines Ltd.	Falconbridge, Ont.	41,500[a]
Gaspé Copper Co. Ltd. (Noranda)	Murdochville, Que.	45,000

a Copper-Nickel Bessemer matte.

The nation's refineries are two in number. One is operated by the International Nickel Company at Copper Cliff, and treats blister copper from the nearby nickel-copper smelters. The other, owned largely by Noranda Mines Limited, is in Montreal East, and is devoted to treatment of copper metal originating in Quebec and Manitoba-Saskatchewan. Together with Inco's refinery, it processes better than 80% of the output of Canadian mines. The remainder is exported either to Norway or to the United States for further treatment. Falconbridge still ships most of its output overseas for refining. All British Columbia production is shipped down the coast to Tacoma for smelting and refining. Finally, the International Nickel Company is continuing to ship a sizable proportion of its output of nickel-copper matte to the United States and the United Kingdom for the production of such alloys as Monel metal.

Because the Canadian market for copper is sizable, more is converted into fabricated sheets and forms (wire, rods, sheets, extruded shapes, pipe, etc.) than is the case with most other non-ferrous metals. Noranda holds a controlling interest in two of the four fabricating companies located here. One is Noranda Copper and Brass Limited whose plant is in Montreal East. The other, the Canada Wire and Cable Co. Limited, operates factories both in Montreal East, and at Leaside, Ontario. One of the remaining two companies—Anaconda American Brass Limited, in New Toronto —is predominantly American controlled, being a Canadian subsidiary of the Anaconda Copper Company in the United States. The other, Phillips Electrical Company (1953) Limited, whose principal works are in Brockville, Ontario, is under United Kingdom control. These last two concerns purchase the bulk of their primary copper supplies from the International Nickel Company.

With the passage of time, an even higher percentage of Canadian mine output will probably be smelted and refined in this country. At one time primary processing was usually performed at a distance from the mines, and prior to World War I there was a relatively large international trade in concentrates and matte. Since the early 1920's, however, this tendency has been reversed, copper in its raw form being smelted and refined close by or

within a few hundred miles of its point of origin. Meanwhile electrolytic refining has become increasingly popular, this process taking the place of the older fire refining method because of the greater purity of the electrolytically refined product. Since the early 1930's, when the Canadian refineries first commenced operations, over 80% of this country's output of ores and concentrates has been refined at home. Now, with plans well advanced for the opening up of several major new copper producing areas, additional processing facilities are being considered. Plans are well advanced for the erection of a smelter at Chicoutimi on the north shore of the Gulf of St. Lawrence. Construction of a smelter and refinery on the west coast of British Columbia has become a popular topic in mining circles in western Canada. New plants may also be built as output warrants in Manitoba, Ontario and possibly New Brunswick. Should they go ahead it is likely that an even higher proportion—possibly in the order of 90%—of Canada's mine output of copper would be processed to the metal stage in this country.

Canada has for many years shipped a sizable proportion of its production of copper rods to other countries. Other fabricated forms have also been sold on the export market, particularly when copper was in tight supply and when the Canadian companies had excess rolling mill capacity. As the latter had been expanded to look after wartime requirements, Canada has, since 1945, been in a position to serve the world demand for copper in these more highly processed forms. Gradually, however, this capacity will become absorbed in meeting the requirements of Canadian industry. Another factor militating against such exports is the progressively higher United States tariff on fabricated and other more highly manufactured shapes. It is noteworthy that the Hudson Bay Mining and Smelting Co. Limited; the Granby Consolidated Mining, Smelting and Power Co. Limited and Britannia Mining and Smelting Co. Limited are all preponderantly American controlled. The first two are incorporated in Canada with head offices at Winnipeg and Vancouver respectively and with executive offices in New York. The third company is a wholly-owned subsidiary of the Howe Sound Company, a United States corporation with its head office also in New York.

With regard to copper itself, as a result of the collapse of the world copper market in the late 1920's, a 4¢ a pound tariff was imposed on new metal by the United States government in 1932. This virtually precluded the entry of Canadian and other foreign copper into the United States until the outbreak of World War II. Thereafter, until 1945, copper bought by United States government agencies was brought in duty-free, the view being taken that the import tax, under wartime circumstances, was not applicable. It was then reinstated for a brief period, following which, in April, 1947, it was suspended by Congress until June 30, 1950. While still under suspension, it was reduced to 2¢ a pound, effective March 16, 1949, as a result of the trade agreements negotiated at Geneva in 1947. This new tax

finally came into effect on July 1, 1950. It was again suspended on April 1, 1951 and this suspension was subsequently continued through to June 30, 1958. The law now provides that the United States Tariff Commission must notify the President within 15 days after the end of any month in which the price of copper drops below 24¢ a pound, under which circumstances the President must revoke the suspension.

(g) *Some Implications for the Future*

As far as Canada is concerned, both copper production and consumption are likely to rise over the next quarter century. Mine output, influenced largely by the discovery and development of other metal resources, may rise by about two-thirds. Industrial requirements in this country, stimulated largely by the growing needs of the electrical industry, may also increase by between 50% and 75%. Were this to happen, the tonnage of new copper available for export to the United States and overseas would be between one-third and one-half greater than in 1955.

These changes may be further magnified by an increase in real price. Market sources generated largely outside of Canada may dictate that the general upward trend of the price of copper, despite recent declines may be perpetuated. When allowance is also made for a somewhat higher degree of processing prior to export, a 25% or even 50% rise in price may be envisaged.

Multiplying the two sets of estimates (volume and unit price) together, we find that, in 1980, Canadian production of copper in all forms may have a value of between $400 million and $500 million. Under these circumstances, it would rank among the first three or four metals, exceeded in value only by aluminum, iron and possibly nickel. Exports of primary forms 25 years from now may be in excess of $250 million as compared with $153 million in 1955. The following tabulation, which is also consistent with the view that Canada may continue to produce about 10% of the world's total supply of new copper, indicates as well the changing value of Canadian copper consumption over the next 10 and 25 years.

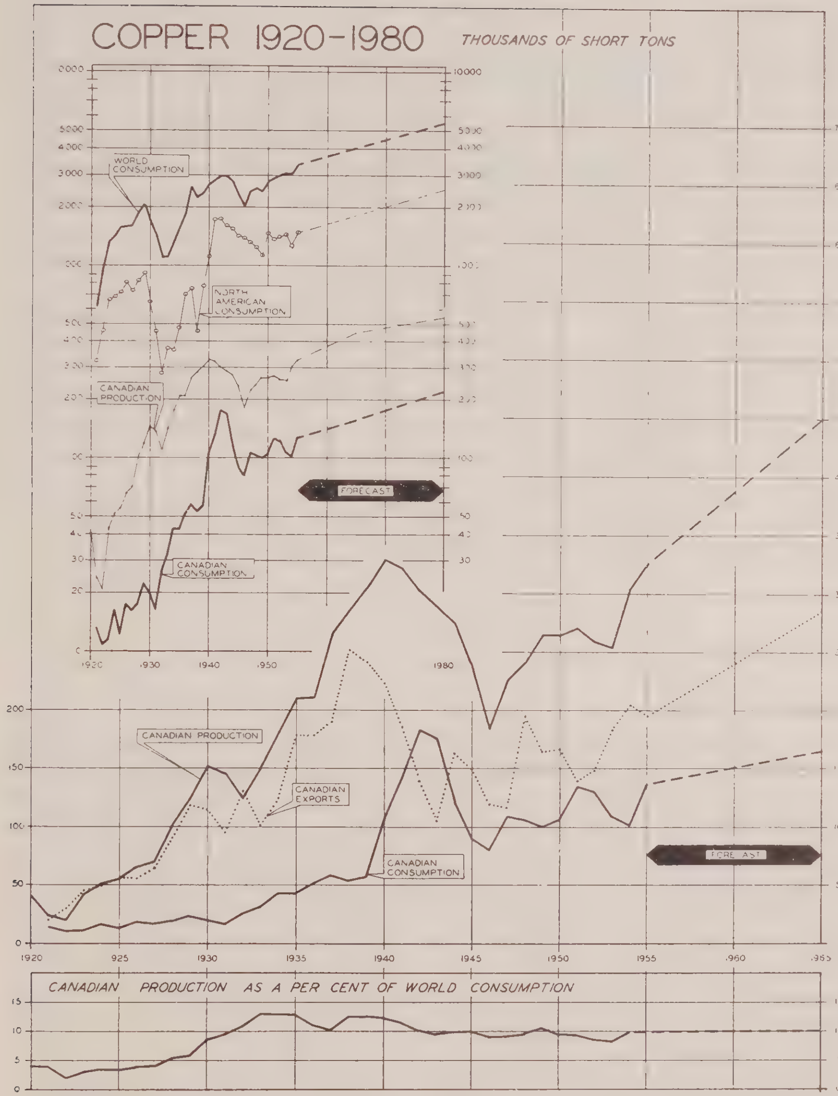
Table 16

COPPER — PRODUCTION, CONSUMPTION, EXPORTS AND IMPORTS, 1955-80

(value in millions of dollars)

Year	Canadian production	Domestic consumption	Exports	Imports
1955	240[a]	88	153	2
1965[b]	330	120	213	3
1980[c]	400	150	255	5

a Works out to about 37¢/lb. for copper in all primary forms.
b Assuming no change in real price.
c Assuming a 10% to 25% increase in real price.


COPPER 1920-1980
THOUSANDS OF SHORT TONS
WORLD CONSUMPTION
NORTH AMERICAN CONSUMPTION
CANADIAN PRODUCTION
CANADIAN CONSUMPTION
FORECAST
CANADIAN PRODUCTION
CANADIAN EXPORTS
CANADIAN CONSUMPTION
CANADIAN PRODUCTION AS A PER CENT OF WORLD CONSUMPTION

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E. Zinc

(a) *Introduction*

Compared with others, zinc is not a spectacular metal. Its long-run growth trend has been nothing like as impressive as some of the more recent arrivals, such as aluminum. Also, consumption has been lagging well behind economic activity generally. Instead of doubling every 10 or 15 years—as is the case with many other goods and services—its pace has been more like that of iron. Worldwide statistics show demand to be reproducing itself at something like 30-year intervals—that is to say, at a rate of between 2% and 2.5% annually. Despite the acceleration which is expected to take place in most other industrial sectors, the accompanying forecast shows a further levelling-off in demand for zinc.

As in the past, consumption will be a function of price and hence of availability and cost. No serious impediments are expected to be encountered on this score. Known and inferred reserves are sufficient to support the world's present level of output until about the year 2000. Hence, a 25-year increase in requirements of 30% can easily be accommodated. Even a 50% expansion in the market for zinc ores and concentrates would appear

manageable as far as supply is concerned. Should new uses continue to develop slowly, the price of zinc might be expected to remain unchanged or possibly decline relative to that of other goods and services.

The outlook for zinc differs in some respects from that for lead. Known zinc ore reserves exceed those of lead in frequency of occurrence, richness and size of deposit. Where they occur together, the zinc-lead ratio appears to be rising. Also, zinc is often found in association with other metals like copper, but lead less so. Recent discoveries have added considerably to established zinc reserves. Estimates of known and inferred lead have been moving upward more slowly. Direct substitution, meanwhile, poses less of a threat in respect to lead. Its price, compared to that of zinc will, therefore, tend to be more stable. Zinc, though by no means one of the younger metals, may continue in its expansionary phase. Lead consumption, on the other hand, could show an even greater tendency to level off in the years between now and 1980.

Zinc, traditionally a relatively cheap metal, is employed for both its chemical and mechanical properties, resistance to atmospheric corrosion and relatively low melting point. Its compatibility with copper in brass and bronze has made these among the more widely used of non-ferrous alloys. Its peculiar properties have also attracted zinc to other and larger volume uses. Including galvanizing, die casting and the manufacture of paint pigments, salts and dry battery components, such uses at present account for nearly 90% of total slab zinc requirements.

With the possible exception of zinc in semi-fabricated form, consumption in most uses is expected to go on rising over the next 25 years. The largest single gain may be encountered in the galvanizing of steel products. This is projected at about half the rate for all goods and services. A more modest increase may be encountered in respect to the production of brass and bronze alloys since a rise in the price of copper would stimulate the demand for alternative aluminum alloys. Relatively at least, some ground may be lost in die casting. Part of this market has been taken over by aluminum-base alloys. Magnesium too, is entering this field. Chemical uses, on the other hand, may continue to grow at a rate at or above the long-run rate for new metal. Meanwhile, the use of rolled zinc may well decline since magnesium, due to its increasing availability, and even greater decline in price and superior performance, may substantially displace zinc in the manufacture of dry cell batteries, engraving plates and in the field of cathodic protection.

Unlike many other metals, the greater utilization of scrap is unlikely to have much effect upon future demand. Proportionately, supplies made available in this way may even decline. For this and the other reasons mentioned, over-all consumption may continue to grow at a rate of between 1% and 2% per annum. Assisted by greater research effort both at the technical and sales levels, world usage may approach four million tons

annually in 1980. This is well above the figure of approximately 2.9 million tons reported for 1955.

Regionally, there will be differences. The future North American demands are variously assessed as between 25% and 30% greater by 1980. Requirements in Western Europe and elsewhere may be more buoyant. Recovering much of their prewar position, usage in the United Kingdom, Western Germany, France, etc. may go up by 40% or more. This, in the face of a levelling-off in mine output in the United States, presumes more than a doubling of production from other sources. Canada, because of its proximity to the United States, may expect to share at least equally in this growing international trade in zinc ore, concentrates and refined metal.

For one thing, Canada has the resources. Conservatively estimated, they are in the order of 20% of the world's proven total. They are high in grade and some can be mined comparatively cheaply, using open-pit methods. Also, their proximity to established industry and markets ensures that both the necessary capital and know-how will be available as and when demand dictates. It is mainly on these grounds that Canadian output, as a percentage of the world's total, has been shown as rising from around 15% at present to 20% or better in the late 1960's and 1970's.

An approximate doubling of mining production is one thing. The net return to the Canadian economy may be quite another. In recent years, a growing percentage of the nation's output of both lead and zinc has been exported in the form of ores and concentrates. At present about half of Canada's zinc output is shipped elsewhere in other than manufactured forms. One explanation for this is the decided shift eastward in the centre of gravity of Canadian zinc production. Another—an even more significant one—has been the growth in zinc exports to the United States. Taking advantage of idle refining capacity, the American companies which have been partly responsible for the developments which have taken place since World War II in eastern Canada have been importing zinc concentrates from Canada.

Anyone forecasting the role which this industry will play in the Canadian economy of the future must therefore make certain assumptions as to degree of processing. Should the postwar trend continue, Canadian mine output will rapidly outstrip production from the nation's smelters and refineries. On the other hand, should the United States' policy with regard to imports become stabilized, a good deal of new refining capacity may eventually be built both in western Canada and in or around the Gulf of St. Lawrence, its purpose being to serve both the American and offshore demands for primary metal.

(b) *Canadian Position*

Over the years Canada's role as a source of zinc metal has been increasing. From its beginning during World War I, it has risen almost

continuously to an output in excess of 400,000 short tons a year at the present time. Compared to total world production, Canada passed the 5% mark in the late 1920's, stabilized around 10% during the 1930's and is presently edging up to 15% as more new mines come into operation. Exclusive of metal in its fabricated forms, the industry's current value of output is in the vicinity of $120 million.

Mine output has increased by one-half since the late 1930's. Since then, growth of about 75% in Manitoba-Saskatchewan and about 25% in British Columbia has been accompanied by a close to fifteenfold expansion in Quebec. Newfoundland output, meanwhile, is less than one-half of its prewar level.[36] Metal production, while it has also moved upward, is located entirely in western Canada. Thus, although zinc metal exports have risen by about 25%, exports of raw concentrates have nearly doubled.

Paralleling this growth has been a shift in markets. From relative self-sufficiency, the United States has become the world's largest importer both of ores and of metal. Canada, in consequence, has become a major supplier of the United States in respect to both. In prewar years, Canadian production was exported almost entirely to the United Kingdom and other overseas markets; its ore trade was largely confined to Newfoundland shipments to the United States. More recently, however, more than half of the nation's metal exports (originating in western Canada) and practically all of the much larger concentrate exports (chiefly from eastern Canada), have been directed to the industrial users of slab zinc and smelters in the central and north-eastern United States.

(c) *World Production and Reserve Trends*

World zinc production is steadily increasing. Since 1950, it has risen by approximately 20%. Further additions to capacity are under way or planned. At the same time, the world pattern in mine production is shifting. Western Europe and Japan have recovered their prewar levels while mine output in the United States, long the world's leading producer, is on the decline. More significant to the supply situation, however, have been the numerous discoveries in such new areas as Peru, the Belgian Congo, French North Africa and eastern Canada.

Measured and indicated world reserves are presently in the order of 75 million short tons of contained zinc or about 30 years of supply at current rates of use. This leaves out of account potential resources or inferred ore reserves, many of which will, doubtless, become better defined with the passage of time. A recent estimate of the United States Bureau of Mines places the latter in the vicinity of 200 million tons at the present time.[37]

[36]In 1955, B.C. zinc production amounted to some 216,000 short tons. Quebec was second with 101,000 short tons and Saskatchewan third with 49,000 short tons.

[37]U.S. Department of the Interior, Bulletin 556, "Zinc", a chapter from *Mineral Facts and Problems*, 1955.

Much of this material, furthermore, may prove to be recoverable at or close to present day mining costs.

Their location geographically is of interest. Reserves in the United States are modest by comparison. At present they are measured in the vicinity of eight million tons of zinc content. Europe, producing more than one-quarter of the world's total output, possesses measured and indicated reserves of around 22 million tons of zinc or close to 30% of the world's total. Half of this is west of the Iron Curtain. Australia, with developed reserves of about 11 million tons, is in an even better balance position in relation to its present 8% of world output. The combined reserves of developed ore in South America have been estimated at six million tons. Lack of development in such highly mineralized countries as Chile, Peru, Bolivia, Brazil and Argentina, however, suggests that very large additions may subsequently be made to those already known there. Much the same thinking applies to a great deal of Africa and Asia, where new discoveries and revisions will continue to be added to the known reserves, now believed to be in the vicinity of eight million tons.

Canada's rapidly changing position is interesting when thrown against this broader world perspective. With presently proven and indicated reserves in the vicinity of 19 million tons, and a potential believed more in the vicinity of 60 million tons, its status as a world producer appears assured for many years to come.

(d) *Trade and Tariffs*

(i) *Ore trade*

In contrast to copper, some 35% of zinc mine output, immediately after concentration, enters into international trade. In recent years, the ore trade, measured in zinc content, has been about twice the size of the metal trade (one million tons compared to less than 500,000 tons of metal).

The development of new refining facilities (mostly electrolytic) in Canada, Norway, Australia, Italy and Poland after World War I did decentralize the refining industry somewhat, but the volume of the ore trade was only temporarily arrested. In the last 15 years it has steadily increased, particularly since 1950.

Large existing smelter capacity in the United States, Belgium, Germany, France and the United Kingdom coupled with a lack of or declining mine production in these countries, provides the current and potential international demand for ore concentrates. Traditionally ore surpluses have been available in Mexico, Australia, Newfoundland, Italy, Spain, Sweden, Yugoslavia and Bolivia. More influential have been new developments in Quebec, Peru and Belgian Congo, and to a lesser extent in other parts of Africa.

Silesian ore production is now entirely inside Poland (the smelters and some mines went to Poland after World War I) and no longer enters into international trade. The substantial prewar production in Burma, once available for export, has been shut down by war and internal unrest.

Among suppliers and consumers certain trade patterns have been built up. Although shifting through time and never entirely definite, they do form a general pattern. The United States requirements in recent years have been met by Mexico and Canada, with smaller amounts coming from Peru, Bolivia and others. The United Kingdom is supplied largely by Australia and to some extent by Canada. Belgian smelters are fed by ore from the Congo and many other countries including Peru, Australia, Sweden and Morocco. France receives in addition to north African ores, supplies from Spain, Greece and Italy. The Netherlands and Germany rely on Peru, Bolivia, Italy, Spain and others.

Some relationships stem from company affiliations, but on the whole this factor is much less influential than in earlier years. American interests in Mexico, Canada, Latin America and Africa are still large, as are Belgian and French interests in the African colonies, Spain and Greece, but commercial affiliations are often overridden by political and economic policies of governments.

In the future, the zinc ore trade may remain large, despite new processing plants in Peru and elsewhere, and such proposals as have been made for eastern Canada. As long as new mine developments continue and competition from old but still efficient processors remains strong, a substantial proportion of mine output will enter into trade. If new mine developments decrease and older smelters become less competitive, the trade may decline. Neither of the latter factors now appears imminent.

(ii) *Metal trade*

International movements of slab zinc, amounting to 450,000 to 500,000 tons annually, are smaller than the trade in ore concentrates. Moreover, it seems that the trading pattern is slightly less complicated and has shown less change than in the ore trade. Many new mining developments have as yet had little effect on the established processing facilities, and as a result most of the change is evident in the trade in concentrates rather than metal.

The United Kingdom, long the largest importer, is now being challenged by the United States (the largest in 1953, though not in 1952 and 1954). American net imports of metal in 1952-54 averaged 135,000 tons annually, while net imports of concentrates have risen to 470,000 tons, both from a near balance in prewar years. Average British imports during 1952-54 have been 185,000 tons. Other importing areas are continental Western Europe, India, South Africa, Brazil and Japan.

Canada and Belgium dominate the exporters, followed by Mexico, Australia, Norway, Northern Rhodesia and Italy. The change from prewar years is very small, reflecting little net change in the smelting pattern.

While Canadian and Mexican producers meet most of the United States deficiencies, roughly a third of Canada's surplus still goes to Britain. The United Kingdom also receives substantial shipments from Australia, Rhodesia, Belgium and Norway. The last two countries supply most of Western Europe's import needs, assisted recently by small surpluses from Germany, Netherlands and Italy. The United States is the centre of a fluctuating *entrepôt trade,* often importing substantial quantities from European and other countries and re-exporting sizable amounts, particularly to the United Kingdom.

The large Polish surplus, gained from Germany by the cession of Upper Silesian smelters after World War I, was available to Western Europe in the interwar period but is now quite effectively shut off by the Iron Curtain. Without doubt this strengthens the position of the Belgian exporters, as well as domestic producers in Western Germany and elsewhere.

(iii) *Tariffs*

Because of international industry integration, tariffs were not of too great concern until 1930, although United States tariffs of 1.00¢ to 1.75¢ a pound on metal, and lower on concentrates, had served to protect domestic industry at certain times.

In the United States in 1930 with prices dropping, duties were set at 1.75¢ and 1.50¢ a pound of metal and ore content respectively. Consequently the United States price became nearly 50% above the world price. This served to isolate completely the United States from the world market, until temporary wartime agreements and the 1947 and 1951 agreements at Geneva and Torquay, which set rates finally at 0.70¢ and 0.60¢ a pound of metal and ore content respectively. At this level most efficient foreign producers can compete with higher cost United States producers, resulting in the present demand for a return to higher tariff rates.

Until 1925 there was considerable competition in the rest of the world for ore supplies, and smelting was concentrated in a few localities, both factors tending to keep down tariffs. However, increasing mill and smelter capacity and rising economic nationalism quickly brought a series of tariff impositions. Polish-German animosity over Silesia led to a high tariff. France, Italy and Spain raised metal tariffs to protect domestic production. Italy and Spain had their own ores, and France, Britain and eventually Belgium developed colonial ore and metal supplies by control, combine or protection. British Imperial Preference of 10% was established in 1931 giving

Australia and Canada a strong advantage in the large United Kingdom import market.

The new tariffs and declining demand reduced the flow of trade particularly in ore. At the same time the tariffs changed many of the traditional patterns of trade. Italy became self-sufficient in metal behind tariffs equal to 75% ad valorem. Germany built new plants under an 86% tariff while existing Polish and Belgian smelters operated at less than 50% capacity. Canadian exports increased and Australian trade was fairly well sustained but Mexico, cut off by American, British, and European tariffs, suffered a cut of two-thirds in production.

Since then, the rise in prices (reducing the impact of specific tariffs), and the War and postwar shortages have until recently overridden protective barriers. In addition, the general trade agreements have lowered the absolute tariff levels. However, the return to the buyer's market again raises the tariff question. The tendencies to economic nationalism, so evident in the 1930's, have by no means disappeared. Domestic production will tend to be favoured in the principal consuming countries, while in Europe, colonial and soft currency areas will also be favoured. Canada and other independent producer-exporters are liable to become marginal suppliers in these major markets, if policies aimed at economic self-sufficiency prevail.

(e) *Prices*

In common with some other commodities, slab zinc is traded on the London Metal Exchange and New York Commodity Exchange, but the trading on the latter is of little importance in the world picture. All the zinc in concentrate form is sold by producer either directly or through a broker to a smelter, and more than 90% of slab zinc is sold direct to the consumer. Nevertheless, the fringe or surplus supplies that are traded for spot or future delivery on the London Metal Exchange often determine the world price. Thus the price at which the Canadian producer of zinc sells his product abroad may be determined by the price at which fringe supplies are traded on the London Metal Exchange, and this price is subject to fluctuations that at times can be very violent. It follows that because of the way the basic price is determined, the price of zinc at a specific time may not necessarily reflect the cost of production plus cost of transportation to market, although these factors are reflected in the long-term average price.

The price of zinc at Toronto or Montreal is commonly quoted on the basis of lower grade zinc (Prime Western) at East St. Louis, f.o.b. per pound. Other grades are quoted at a fixed premium on Prime Western, e.g., High Grade was 1.35¢ a pound higher and Special High Grade (which includes most of Canada's output) was 1.50¢ a pound higher. These premiums were reduced respectively to 0.6¢ and 1.0¢ on January 14, 1957. The London

Metal Exchange sets the market for overseas sales and, allowing for the United States tariff, the prices are usually about the same.

Over the years the price of zinc has been subject to wide fluctuations. The lowest price was 2.10¢ a pound in 1932 and the highest 22.14¢ a pound during July, 1915. During and after World War II the price to Canadian consumers was controlled at 5.75¢ a pound. When controls were lifted early in 1947, the price increased sharply to 10.25¢ and in the period 1948 to 1952 ranged between 10¢ and 20¢ a pound. During 1955 the price ranged from 11.5¢ to 13¢ a pound ending the year at the latter figure. Owing to the favourable supply situation and the competition from aluminum and other metals, zinc may show moderate decline in real price during the next 25 years.

(i) *Supply factors*

There are a great number of zinc mining and smelting companies, particularly in the United States, Western Europe and Japan. This tends to greatly reduce the possibility of close control of production in relation to demand. Declining demand may lead to intensive price competition and drastic price cuts. Such was the case during 1952-53, when demand fell and production increased in Canada, United States and Western Europe. In the United States, from early 1952 to early 1954, prices fell from 19.5¢ to 9.5¢ and stocks increased from 23,000 to 210,000 tons. Moreover, in periods of high and rising demand, custom smelters are not always able to secure sufficient ore supplies immediately from independent mine operators. The more centralized metal industries (nickel, aluminum, magnesium) are able to cut back production more readily and at the same time keep some capacities in reserve to meet returning demands.

The more integrated electrolytic zinc producers in the western United States, Canada, Australia and elsewhere are faced with the very high fixed costs of their complex capital equipment. The necessity to maintain near capacity production at almost any price, in order to cover these fixed costs, is always a strong deterrent to large reductions in output. But the zinc distilling companies (many without mining facilities) with high current costs for fuel, labour and sometimes ore, and less capital equipment (much of it paid off anyway because the plants are older), are more willing to reduce operations when prices decline and return when prices are stronger. For example, in February, 1954, when zinc was down to 9.5¢, United States primary zinc output was cut back about 13,000 tons monthly or nearly 17% of the 1953 rate of production. However, electrolytic production was reduced by only 6% or 7%, whereas the fuel-using distillers closed down over 20% of their facilities. Thus when demand and prices are declining, the electrolytic producers tend to become the price leaders in their drive for volume; whereas in periods of increasing demand and output, the fuel

smelters tend to be price leaders, as they compete on a rising market for fuel and labour (and also for ore concentrates in the case of custom plants).

Because most zinc is mined with lead and silver, there have been occasions when a strong demand for one metal has lead to an oversupply of the others and reduced prices. This does not unduly disturb lead-zinc-silver operators who rely on a combined price. Single metal producers, however, are often hard hit when these divergencies in demand for lead and zinc occur.

(ii) *Demand factors*

The fluctuations in demand for zinc are probably not any greater than for other metals, except lead. Nevertheless, the dependence of zinc on the demand for die castings in automobiles and other consumer durables, for brass in ammunition and hardware, for galvanized building products and for paint pigments, results in a marked fluctuation in the monthly as well as annual levels of zinc purchases. Most of the zinc products are used in new goods, in contrast to replacement or repair uses, and are thus subject to the variations in demand for durable goods. On the other hand, the demand for lead is stabilized to a large degree because of the substantial use in replacement batteries in automobiles and in tetraethyl lead additive for gasoline.

In general, zinc prices are less stable than those for aluminum, nickel and copper because of a lesser degree of control over supply, whereas they are less stable than lead prices because of greater variations in demand.

(iii) *Competition and substitution*

In recent decades zinc has been able to replace other metals because of its relatively low price and particular qualities. Galvanized sheet has replaced much of the demand for copper and lead sheet in roofing, etc. Zinc die castings have replaced brass and steel in many automobiles and other items. Zinc pigments have replaced similar uses of lead.

Now, the replacement of zinc by aluminum, or even plastics, magnesium and other new materials, is considered a possibility. These materials make excellent die castings and fine protective coatings, the major functions of zinc. The necessity of maintaining a competitive price is obvious. In order to compete, zinc must sell at a substantially lower price per pound than aluminum because the latter has more than twice the volume of zinc for any given weight. Already aluminum has surpassed zinc by volume employed for die casting purposes in the United States. The former is also used in roofing and similar corrosion resistent items in increasing quantities. However, zinc has been able, up to the present, to maintain a more competitive position in regard to aluminum than have lead and copper.

(f) *Long-Term Market Trends*

The future demand for zinc may be assessed in several ways. It may be determined by projecting historical data as to world consumption. A possible refinement would be to extrapolate similarly regional or national demand trends. Useful, particularly in its qualitative aspects, is an appraisal of zinc requirements by end-use. Since the latter also helps to bring out the relationship of zinc with other metal sales and particularly the effects of competition from alternatives such as the light metals and plastics, it is helpful both for analytical and descriptive purposes.

Historically, world consumption has been rising at a long-run average rate of over 2% per annum. Since the turn of the century it has been more in the order of 2.5%. In the United States, over the past 50 years, it has approximated 2.25%.

Were there to be evidence that zinc, from now on, would be entering a more mature phase, there would be grounds for selecting a progressively lower rate for future expansion. However, there are few signs which would corroborate this assumption. Allowing time for new capacity to be brought in, and adequate supplies to become available, the total cost of mining, transportation and processing will not necessarily rise during the 25-year period under review. Also, because of its unique properties and because zinc has yet to be promoted on its own merits in competition with other materials to anything like the same degree as has been the case with, say, aluminum, the possibility of its holding many of its older markets and developing new ones appears to be good.

With these considerations in mind, it seems inadvisable to set our projected rate of growth below 1.5% per annum. Projected to 1980, this would result in a figure for world consumption of four million tons. Regional analyses tend to substantiate this view. Figures prepared by the industry commonly project demand in the United States as continuing to rise at a rate of better than 1% a year. With the United Kingdom and Western Germany gradually returning to the prominent positions which they occupied in world zinc trade prior to World War II, consumption in Western Europe, for at least a decade, may mount at something like 2%. Elsewhere, increased availability and rising levels of capital investment and consumer expenditure might well result in an even greater acceleration in requirements. Provisional estimates arrived at in this way indicate an aggregate requirement for new zinc in 1965 of approximately 3.4 million short tons.

Now as to uses. The largest single use of zinc, galvanizing, at present employs about 40% of all metal consumed in the United States, 30% in the United Kingdom and 45% in Canada. Zinc coated steel products, including roofing and siding, wire products, hardware, pipe, conduit, and exposed structural steel are in increasing demand. Meanwhile, the introduction of

continuous hot-dip galvanizing with new and superior zinc alloy coatings, containing a small quantity of aluminum, offers further economies in production. For this reason, zinc may well resist—because of its cost advantage—the invasion which aluminum sheet and aluminum coating have recently been making in this field.

The demand for sheet steel and like products, meanwhile, has been shooting upward relative to other iron-base materials. Compounding at a rate more in the order of 4% per annum, they may serve to do two things, collectively and through the process of galvanizing: namely, to increase the relative importance of galvanizing in the use pattern of zinc and, secondly, to sustain or even increase the over-all rate of demand for zinc metal generally.

Zinc alloys are still popular for die casting purposes since they may be cast and finished by plating at relatively low cost. The automotive industry uses zinc die castings extensively for the manufacture of its fuel system components, instrument panels, decorative trim and the like. Zinc die castings are also used extensively in electrical appliances, business and other like machines, tools, building hardware, toys and novelties.

Though much is heard of the inroads which aluminum is making, zinc possesses certain advantages which, at a price of less than half that of aluminum, give it an inherent advantage in die casting and other fields. Its lower melting point which increases die life, together with a possible decline in the real price of zinc, should therefore keep zinc in a competitive position. Large quantities of zinc were consumed for brass making, especially in wartime. In the early 1940's, for example, nearly half of the slab zinc used in North America was consumed in this way. More recently, a figure of 15% has been more commonly encountered. Developments in weapons and ammunition, in the interim, have lessened defence requirements for brass. Civilian requirements, on the other hand, show fewer signs of diminishing, although substitution by aluminum in many fields is an ever present threat.

Some applications may be lost through the introduction of other metals in lieu of zinc sheet and rolled forms. On the other hand, zinc pigments and chemicals are finding additional uses almost daily. Employed in rubber, paints, ceramics, textiles, papers and floor coverings as well as chemicals in the oil refining, wood preservation, soap and fertilizer industries, a relative increase rather than a decline in this component of demand may be anticipated.

Relatively few substitutes for zinc are available in chemical applications. Aluminum and magnesium could replace zinc to some extent as reducing agents in chemical reactions. In the paint industry, lead and titanium pigments can be used instead of zinc pigments in many instances. Titanium pigments have already replaced lithopone to a marked extent, but they sup-

plement rather than compete with zinc oxide in most paint formulations. Titanium dioxide has made inroads on the use of zinc oxide in porcelain enamels. As for opacifiers titanium and zirconium compounds have replaced zinc oxide only in part.

In general, there is little necessity to seek substitutes for zinc, as ample quantities of zinc in the various grades are available at relatively low prices in world markets.

The use of zinc in die casting, particularly, has been lagging behind in Western Europe. Presumably, its greater availability, together with the greater adoption of mass production methods will tend to enhance sales of this metal in that general area. The mass production of cars which accounts for most die castings has not reached in Europe the proportions it has in North America. There will be a marked increase in die casting, however, because it is a cheap production method which has not been fully exploited. Applications, however, will be different, especially with regard to automotive uses. Weight saving is very important because of much higher gasoline prices in Europe. Most use is expected to be in domestic equipment and similar consumer goods. The relative prices of aluminum and zinc in Europe will probably be more favourable to zinc than in North America. This would be true particularly if protective tariff, tax, quota or other measures resulted in a comparatively high zinc price level in the United States.

(g) *Prospects for Canada*

Canada's production of zinc has risen steadily over the past 40 years. From a few thousand tons in 1916, it passed the 400,000 ton a year level in 1953. Meanwhile, Canada's share of world production has been maintained. Currently it is in the order of 15% of total world output.

The Canadian reserve position is strong. The industry is actively developing known deposits and exploring for new ones. Many millions of tons of presently known Canadian metal can be mined and processed profitably at present and prospective prices. Meanwhile, the more or less static position of the mining industry in the United States ensures that sales in that country will show a progressive increase over the period under review.

Because of this strong supply and competitive position, because of its corporate relationships with the United States refiners and other users, and because of sales possibilities elsewhere, the Canadian industry will doubtless expand. The exact extent to which mine output may increase is, of course, much more a matter of conjecture. Relative to over-all world consumption, it may move upward. Possibly it will reach a relationship in the order of 20%

in the late 1960's, which it could well maintain, or even improve on, in the 1970's and 1980's. Quite arbitrarily, Canadian mine output, presently in the order of 430,000 tons, has been put at 650,000 tons for 1965 and 800,000 tons for 1980.

Value estimates are even more difficult to prepare. They involve assumptions both as to real price and as to the extent of processing of Canadian ores and concentrates prior to export. In all likelihood the price of primary zinc will fall relative to that of other goods and services. A drop of 10% by 1965 and 20% by 1980 is envisaged. Secondly, it has been assumed that the present 50:50 ratio of refined metal production to mine output will be maintained over the next quarter century.

The resultant forward estimates for zinc in all forms apply to an average year in the mid-1960's and 20 to 30 years hence.

Table 17

ZINC, VOLUME AND VALUE ESTIMATES, 1955, 1965 AND 1980

	Volume in thousands of short tons			Value[a] in millions of dollars		
	1955	1965	1980	1955	1965	1980
Production	427	650	800	118	159	172
Exports	404	610	740	71	97	104
Domestic consumption[b]	58	70	100	45	49	62

a Assuming a 10% drop in real price by 1965 and a 20% decline by 1980.
b Including an allowance for some imports and domestic inventory changes.

(h) *Changing Structure of the Industry*

In Canada, beginning in 1898, sporadic shipments of zinc ore and concentrates were made from mines in southern British Columbia to refineries in the United States. However, it was not until 1916, when an electrolytic zinc refinery was brought into operation at Trail by The Consolidated Mining and Smelting Co. of Canada Ltd., that production really got underway on a large scale. Thereafter, Canadian mine and refinery output moved steadily upward, one more or less in step with the other.

A second electrolytic zinc refinery was built at Flin Flon, Manitoba, by the Hudson Bay Mining and Smelting Co. Ltd. Though smaller than the British Columbia smelter, it also served to convert into primary metal most of the zinc-bearing ores produced in that part of the country. Up until the commencement of World War II,[38] and especially since 1945, mine produc-

[38]Western Canada still produces about 60% of Canadian zinc mine output. The capacity of the Sullivan Mine (Consolidated Mining and Smelting) is in the vicinity of 12,000 tons of ore per day; that of the Hudson Bay Mining and Smelting mine at Flin Flon about 6,000 tons daily. There are some 11 additional producing mines in British Columbia and the Yukon, with tonnages ranging from 100 to 3,500 tons per day, and several smaller ones. In Manitoba, there are at present two small producing mines besides the much larger one at Flin Flon.

tion in eastern Canada has been on the increase. First in Quebec, then, more recently, in the Maritime Provinces, new properties are being opened up and old ones expanded. Including the output of the Buchans mine in Newfoundland, which has been operating continuously since 1928, these properties now account for about some 40% of total Canadian zinc ore production. With a few minor exceptions, all of their output is exported in concentrated form for processing elsewhere. In recent years, some 70% of this raw material has been destined for smelters in the United States; most of the remainder is shipped overseas to Belgium for further treatment.

Over the next few years, considerable additions will be made to Canadian mine capacity. Of particular interest is the property of The Consolidated Mining and Smelting Co. at Pine Point on Great Slave Lake in the Northwest Territories. Here, a very substantial reserve of comparatively high-grade lead-zinc ore lies close to the surface. Relatively high in zinc, the thickness of the overlaying strata is such that much of this material can be recovered using open-pit methods. Though the timing of its development is contingent upon the construction of a 430-mile railway connecting it with existing lines in northern Alberta, present information suggests that this metal can be recovered profitably at present day prices and using presently known mining techniques.

At least four large base metal deposits have also been located in the Newcastle area of New Brunswick since 1952. Like the reserves mentioned previously, a good deal of this material can be mined cheaply using open-pit methods. It has the attraction of being close to tidewater and can thus be transported cheaply to market. Though comparable in grade, the very fine grain nature of these ores may, for a time, result in processing difficulties and a certain amount of wastage at the concentrating level.

In Ontario, at Manitouwadge, just north of Lake Superior, large copper-zinc deposits are being developed. Other properties are also being opened up close to Sudbury and several places in Quebec. It is also possible that additional mining may commence in Newfoundland and Nova Scotia within the next few years.

It is thus apparent that markets rather than the availability of ore are likely to be the main determinant of growth. Domestic requirements are comparatively small. Fluctuating chiefly as a result of defence demands, consumption in this country is presently in the order of 50,000 tons or approximately one-fifth of the total of the nation's mines. Though the long-run trend in these metals will, doubtless, be upward, local requirements are

not likely to be such as to take care of a fraction of the new mine capacity which is likely to be introduced in Canada over the next five to ten years.

Hence the development of export markets will continue to be the industry's main concern. Established outlets both in the United States and overseas will be relied upon to take Canada's present output of primary metal. The ores and concentrates presently originating in central Canada will probably continue to flow south or eastward mainly to smelters which would otherwise be operating at less than capacity in the United States. Existing corporate ties will also tend to perpetuate this trade.

Once the Pine Point reserves are opened up, they are likely to be processed electrolytically or chemically with the aid of natural gas in western Canada. Much the same may be true of other materials originating in the Yukon and British Columbia. The future, as far as initial manufacture of the large New Brunswick deposits is concerned, is less clear. Since hydro power is locally expensive and limited in amount, treatment by electrolytic methods is less advantageous than elsewhere. Fuel, and especially coal, is expensive as compared with the more favourably situated sites down the eastern seaboard in the United States. Also, the ever present threat of United States import tax or quantitative restrictions has to be taken into account. These factors, together with the associated problem of by-product disposal, will tend to delay the establishment in this country of processing facilities commensurate with the Canadian industry's ability to mine zinc ore.

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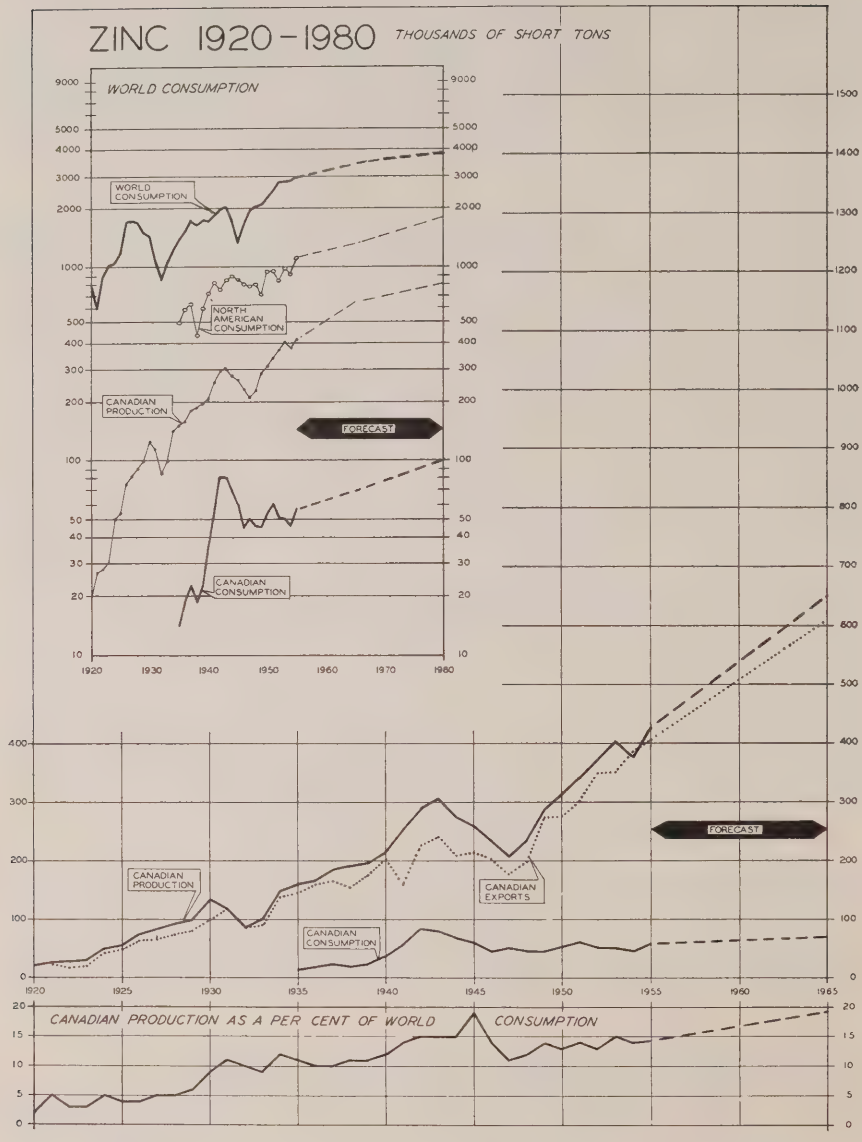

ZINC 1920-1980
THOUSANDS OF SHORT TONS
WORLD CONSUMPTION
WORLD CONSUMPTION
NORTH AMERICAN CONSUMPTION
CANADIAN PRODUCTION
FORECAST
CANADIAN CONSUMPTION
CANADIAN PRODUCTION
CANADIAN EXPORTS
CANADIAN CONSUMPTION
FORECAST
CANADIAN PRODUCTION AS A PER CENT OF WORLD CONSUMPTION

F. Lead

(a) *General Introduction*

Lead, in contrast to most of the other minerals discussed in this report, can be described as a mature metal. Known and used for centuries, it has been displaced from a number of its traditional applications by other mineral and synthetic materials, commodities which have proved more suitable for the purposes for which lead was formerly employed. World consumption has, therefore, shown a long-run tendency to level off. Supply, though generally adequate in recent years, has also reflected the inability of the world's major producers to create new mine capacity substantially in advance of demand.[39] Neither has the price of lead lagged behind that of other commodities to an extent sufficient to stimulate the rapid development of new uses, the introduction of which would result in greater interest in exploration and development.

This is not to suggest that world consumption will decline in future. Instead, over-all requirements may be envisaged as edging steadily upward over the next 20 to 30 years. Though there will be few problems connected with supply, the demand for lead will probably lag even farther behind that of the majority of other metals. Since the late 1920's consumption has increased by only about 30% in North America. For the world as a whole production has similarly trended upward at about 1.5% per annum rate. The more extensive utilization of construction scrap, battery scrap and others has been one of the causes. Well over one-third of the supply stream is now recovered from previously manufactured articles. Another has been its replacement by entirely new mineral products. One example is the extensive use of titanium dioxide in paints; another the increasing popularity of aluminum and the chemical plastics as building materials. These influences, together with the increasing durability of a number of improved lead-using products such as motor vehicle batteries, and the relative ease of recovery of secondary lead from many of its applications, have helped to minimize what under other circumstances would have been a much more persistent upward trend in consumption.

That new demands have to some extent replaced the old follows from the fact that new lead sales are presently at an all-time high. Further advantage is being taken of the metal's unique properties of softness, extreme workability, high specific gravity, good corrosion resistance and impenetrability by short-wave radiation. New alloys of lead are continually being introduced. Chemical applications, particularly the manufacture of tetraethyl lead (used as an anti-knock agent in gasoline) are also expanding at a relatively high rate, thanks to the growing number of automobiles. Symptomatic of technological developments which from time to time may also require lead metal to

[39]Lead production is tied closely to that of zinc, and therefore indirectly to the market for zinc.

be used in appreciable quantities, is the demand which is developing for it as a shielding material in nuclear reactors.

Relative to most other producing nations, Canada's position is one of strength. The nation's proven reserves are considerable, and substantial additions to this country's lead mine capacity are either in train or can be made at comparatively short notice. Mining costs are low and those resulting from operations in new properties are likely to be favourable. The United States, meanwhile, is becoming increasingly a net importer of lead ore, concentrates and refined metal. Defence considerations also favour Canada as a source of supply to North American industry. A substantial volume of lead in raw and semi-manufactured form may also be sold overseas. Thus it would appear that Canada's position as a world trader in primary lead in its various forms is likely to improve both relatively and absolutely during the forecast period under review

(b) *The Canadian Position*

Though lead output in Canada has, as yet, to regain the level which it reached in the early 1940's, it continues to be a significant item of trade. Value of production equals about one-fourth that of nickel, one-fifth of aluminum and less than one-half of zinc.

However, Canada's position as the world's fifth largest producer after the United States, Australia, U.S.S.R. and Mexico, and third ranking exporter after Mexico and Australia, is currently being challenged. Rapid growth in Peru and French Africa, as well as in Russia, coupled with the postwar decline in Canadian output, has reduced this country's share of the world total. This, in 1955, approximated 10% of world mine output, about 7% of total lead metal production, and about 17% and 14% respectively of the world's international trade of ore and refined products. Canadian consumption, by comparison, is still less than 3% of the world total.

But the postwar rehabilitation of existing properties, together with new discoveries, indicates a rising trend in Canadian capacity—one which compares favourably with most other major producing areas. Some decline in output from the British Columbia mines, as well as from Newfoundland, combined with increased domestic consumption, resulted in a substantial drop in postwar exports. More recently, this has been offset by the greater sale abroad of ores and concentrates from Quebec. Meanwhile, as with other metals, a decided shift in markets has occurred, the United States having substantially replaced the United Kingdom and Japan since 1940. Future increases in output can be expected as a result of new production from mines in New Brunswick and in the northeast Territories. It is also expected that most of this new production will find an outlet in North America, moving to market in the form both of concentrates and refined metal.

(c) *The Changing Pattern of Trade*

Right up until World War I, there was a wide geographical divergence between mine and metal production, with large shipments of ore being made from countries like Australia to smelters in the United Kingdom and continental Europe. Since then a good deal of smelter capacity has been built in or close to the mining areas themselves, the older facilities having been closed down or converted to the recovery of secondary lead from scrap material.

An encouraging feature has been the relative simplicity of the smelting process whereby lead can be recovered in metal form from its better known ores. These were usually found in comparatively rich pockets without other metals being present. Meanwhile, the recovery of lead in association with zinc and silver was, at times, delayed. Until the introduction of selective flotation in the early 1920's, the more complex western bi- and tri-metal ores had little commercial value. This development had important implications for Canada. It resulted in the extensive Sullivan deposits at Kimberley becoming a mine. More than that, it made available a wider range of products to an industry which was subsequently better able to meet changing market conditions and, through a higher metal content in its ore, to compete effectively with the lowest cost producers elsewhere.

Various countries have led in metal production over the years. At one time France, England, Spain and Italy produced considerable quantities. However, with the completion of the first transcontinental railway, mine production in the United States increased rapidly. So much so that the United States became the world's largest lead producer in the 1880's—a position which it still holds, though with a decreasing margin over its nearest competitor, Australia.

World War II marked the beginning of United States dependence on imports for a large portion of its needs. For many years that country had been self-sufficient but, beginning in 1940 and continuing thereafter, increased domestic requirements necessitated large imports from Mexico and Canada.

World production of primary and secondary lead in recent years has been in excess of world requirements. Consequently, large stocks have accumulated. In 1950 and 1951, consumer demand and the stockpiling programme in the United States not only stimulated further production but also absorbed much of this excess output. When, in 1952, stockpiling and world consumption were both cut back, prices began to fall. The United States market, meanwhile, served to attract a continuing high level of imports. A number of their higher-cost mines, as a result, were forced to close down, mine production in that country reaching its lowest ebb in 20 years. A revival of stockpiling, with preferred contracts going to American mines, has effected a substantial recovery of United States mine production. Thus,

for the time being at least, Canadian producers are assured of reasonably free access to the United States and other world markets.

(d) *Long-Term Market Prospects*

The demand outlook for lead is problematical. Various statistical projections can be made, the most optimistic of which points to a 50% increase in world requirements over the next quarter century. Yet there is in the long-term record sufficient indication of a progressive levelling-off to warrant a forecast of little change in consumption over the period under review. An examination of lead's changing end-use pattern and varying regional markets, when taken in conjunction with the more likely supply possibilities, leads to estimates falling somewhere in between the more optimistic and pessimistic of these views.

Over the last 20 to 30 years, world requirements have been rising at a little better than a 1% per annum rate. Augmented by motor vehicle storage battery and gasoline additive requirements of the automobile, consumption has increased by approximately 30% over the past quarter century. Were these various needs to be projected at a comparable rate to 1980, total world requirements for primary metal would be seen to rise from the present level of around 2.2 million tons to between 2.5 million and 3.0 million tons a year.

The farther back one follows the history of consumption, the more apparent becomes the progressive bending over of the lead demand curve. Fitting a mathematical trend line to these data, one would find world lead requirements reaching a maximum of around 2.3 million tons in the early 1960's, remaining relatively constant to about 1975 and declining thereafter. Such a tendency has important implications as to price. Lead, produced along with zinc as well as in its own right, would tend to be in continuous over-supply. Its real price (that is, relative to other goods and services) would be unlikely to rise under these conditions. Indeed, it might decline. Were this to be the case, lead might retain a foothold in numerous applications where substitutes are making heavy inroads at present. Other uses, encouraged by a ready supply of metal, could also develop. These happenings, if they occurred on any scale, would tend to invalidate the demand forecast itself. A levelling-off in the world demand for lead has therefore been taken as a lower limit to our forecast possibilities.

As to main uses, lead has been and still is a metal whose major applications are in transition. Its structural applications have been dwindling; those of a chemical or dissipative nature have either become stabilized or increased. White lead has been replaced by other pigments in white paint; lead foil has almost disappeared from use; lead pipe has given way to copper tubing; and lead sheet has lost out to galvanized iron and aluminum substitutes. Cable

covering, still a major use, is threatened by combinations of aluminum and plastics. Lead ammunition is virtually a thing of the past. In this general sector, only solder, caulking and type metal have expanded along with the general increase in economic activity, and these uses account for only some 10% of consumption. Even in these applications, it is doubtful whether lead will continue in an unassailable position.

The gasoline engine, first through the storage battery and later through the medium of anti-knock compounds, has been the principal factor stabilizing the demand for lead. The impact was first felt in the early 1920's and has since risen to almost 50% of all the lead used in North America. Until recently, this influence had been less notable in Europe. There, largely for historical and supply reasons, construction applications still continue to dominate the market. But the resurgence in gasoline consumption has helped to mask the general trend away from structural applications which has so far been more apparent in North America.

Interestingly enough, substitution and the emergence of new uses has led to more stability in demand rather than less. The major automotive uses (batteries and high octane gasoline) are related more to operation and replacement than to original production. The structural applications, which have been more sensitive to economic fluctuations, are a diminishing factor and military requirements are less of a market determinant than is the case with most other metals. Lead consumption, therefore, did not decline as much as did that of most other metals during the early 1930's nor was it really in short supply during World War II or the recent Korean emergency. It was, in fact, rather in oversupply. This comparative stability, both in the long and medium terms, is likely to be a continuing feature of the market for this important Canadian mineral.

Meanwhile, further shifts between applications will doubtless occur. Of the major uses, tetraethyl lead appears to have the greatest possibilities for expansion. Though affected by improved refining techniques and eventually to the more extensive use of the gas turbine engine, lead will be required in this form for purposes of improving the combustion efficiency of conventional gasoline engines. As long as this particular fuel market continues to grow, at something in excess of a 4% per annum rate, further strength can be expected from this quarter.

Storage battery production currently consumes about 30% of the North American lead supply. The volume has, however, been stabilized. Indeed, despite greatly increased automotive registration, battery production is using little, if any, more lead than in the immediate postwar years. This has been brought about by improved construction and the use of the 12-volt system, both giving an extension of average battery life. Much of this metal, however, is recoverable, therefore being used over and over again. No sub-

stantial short-run increase in demand is therefore envisaged. Over the longer period a lack of satisfactory substitutes, together with the need to support a substantial increase in motor vehicle population, may see some growth in consumption in this quarter.

Two important substitutes, aluminum and polyethylene, have already made inroads into the use of lead for cable covering. It is expected that, despite a substantial increase in cable applications, the use of lead for sheathing purposes will remain about static, further losses in inside uses being more or less offset by the greater acceptability of lead in exterior electric power and telephone cable applications. Cable covering now accounts for about 10% of the total North American demand for new metal.

Elsewhere in the structural field—that is, in respect to the production of bearing metals, brass and bronze, solder, type metal, caulking materials, foil and other uses involving lead in sheet form—the market is expected to remain at or about its present level. In each of these applications, substitutes have already taken over part of the market or are currently being introduced. In other cases lead is being more effectively used. Thus the same result is attained with a lesser consumption of new lead metal. In the building industry, lead is losing out to aluminum, synthetic resins and certain non-metallic materials. The foil market has already been significantly reduced by the greater use of aluminum and plastics. Non-metallic fibres and plastic compounds are performing the caulking function. Magnesium plates are replacing lead in the printing field. Finally, the use of aluminum and aluminum-coated steel as a replacement for lead in terneplate (sheet iron coated with an alloy of lead and tin) and the development of new bearing alloys using other materials may be further extended in the future.

The development of substitutes for lead in paint pigments has proceeded rapidly during the past few years, reducing or eliminating entirely the lead content of paints. Titanium, and to a lesser extent zinc, have been responsible for this invasion of what was formerly one of lead's major markets. Now paint pigment production takes only about 10% of all lead used.

Other lead applications, however, appear to be growing. A possible offset to the above substitutions may be found in the greater use of lead compounds, particularly in the ceramic field. Leaded glasses for television tubes are in increasing demand, as are low melting point, high-lead glazes for aluminum and steel sheet. In most of these uses the value of the lead consumed is low in comparison to that of the end product in which it is contained. Here, as in numerous other applications such as nuclear shielding where the metal's high density, resistance to radioactivity and other physical properties are of immense value, demand is likely to go on increasing during the period under review.

In North America, scrap accounted for about 25% of total lead metal supply in the late 1920's. At present its contribution is well over 40%. With its long history of accumulation and the recent stability of total consumption, industry is approaching a stage of optimum recovery. Other metals, still growing in use, have yet to reach this phase in their development. From this it can be argued that with a further increase in the dissipative uses, new metal requirements may have to come increasingly from new mine production. Here it has been assumed that the present 60:40 new-to-secondary ratio of supply will be maintained through to 1980.

On balance, there would appear to be little ground for extreme optimism or pessimism. Given an active market development programme, the total lead requirements may continue to rise but at a moderate rate. Meanwhile, it would appear that, short of unforeseen technological developments favouring its greater use, lead should also continue to be in good supply. Regional considerations, though they point toward somewhat greater usage in the future, are also consistent with the view that the long-run price of lead is unlikely to rise substantially above its present figure.

Until World War II, more lead was used in Europe than in the United States. Over the past 15 years this position has been reversed. The United States now absorbs over 40% of the world's refined metal supply, followed at some distance by the United Kingdom, Russia and Western Germany. It is altogether possible that, with continued recovery in Europe and a rising standard of living elsewhere, the higher North American demand growth rate may become characteristic of these other areas as well. Should this occur, world requirements might rise by over 25% to around 2.8 million short tons in 1980. About midway between the upper and lower limits of world consumption mentioned previously, this forecast of annual new metal consumption is the one employed as a basis against which Canadian lead production prospects are assessed later in this section.

(e) *Some Supply Considerations*

As we have seen, zinc production has caught up to and then surpassed that of lead. As late as 1930, the world lead-zinc ratio was in the order of 1.25 to 1. More recently it has been about 0.75 to 1. Four tons of zinc are now being mined to every three tons of lead. That this is more than a passing phenomenon is reflected in consumption statistics which show a comparable reversal in the demand for these base metals.

There is no one explanation. Technology has played a part. Flotation, as a method for the selective concentration of lead-zinc ores, was introduced in the early 1920's and made a considerable difference in the amount of zinc recovered. By increasing supply in this fashion, it helped to meet, and in part to create, new demands for zinc which were not forthcoming in the

same fashion in the case of lead. Then there is the physical phenomenon which has commonly been encountered in most lead-zinc mines, that of an increasing amount of zinc and a decreasing amount of lead as operations proceed to depth. In Canada, this has been true of the famous Sullivan Mine in southeastern British Columbia. Nor is it only the older properties which are turning out more zinc. More zinc is being found in association with copper. Some straight zinc mines have also been found and developed in recent years. Little success of a comparable nature has been reported with respect to lead. These are among the reasons why an even lower lead-to-zinc ratio might be expected in the 1960's and 1970's.

In the previous section, dealing with zinc, world production was forecast as approaching the four million ton level in 1980. A lead-zinc ratio of 0.75 to 1 (as is present experience) would put world lead production at three million tons a year by that date. A 0.65 to 1 ratio, on the other hand, would result in a primary production of something like 2.7 million tons 25 years hence. Taken in conjunction with a possible increase in the supply of secondary metal from scrap, the latter seems to be the more likely figure of the two.[40] It would, at the same time, accommodate a rate of increase in metal consumption falling midway between the upper and lower demand forecasts discussed previously.

There is no question of scarcity in the absolute sense. World reserves, measured and indicated, are known to be in excess of 40 million tons. This is equivalent to about 20 years of supply at the present rate of consumption. Reserves of inferred ore are probably as much again. Thus a 2.5 million to three million ton a year requirement could be sustained for several decades without the necessity of opening up entirely new areas for production.

Though the United States lead mining industry is much larger in terms of production, its reserves are presently put at about 2.5 million tons, or about 6% of the world total. Mexico, the other major supplier of the United States, has about one million tons of proven lead content or about 2.5% of world reserves. Dominating the scene is Australia with over 30%. Lesser, though significant quantities of metal are also known to occur in Eastern Europe (around 17%), Africa (over 8%), South America (6%) and Western Europe (around 7%).

That Canada is likely to participate increasingly in this trade is evidenced from the available data on her proven reserves. These are at present in excess of seven million tons, or between 15% and 20% of the world's total. Considerable additions may be made as the result of the drilling up of resources at Pine Point in the Northwest Territories and the Bathurst area in New Brunswick. Being comparatively high grade and readily mined, they are also likely to become commercial well before numerous other and more scattered deposits in other parts of the world.

[40]The average lead-zinc ratio in Canada is 0.40 to 1.

(f) *The Outlook for the Canadian Industry*

Modest increases in production seem likely to occur in Canada's case. Mines already in operation in this country have 30 to 40 years structure of reserves ahead of them at present rates of production. Also, the cost structure is favourable. For these reasons, and because of a levelling-off of production elsewhere, they should continue both to meet the needs of the Canadian market and to share in such growth in demand as is likely to occur in the United States. Overseas sales, while they are more likely to be affected by the development of new mine capacity in other countries, may remain about the same or possibly increase in the years ahead.

That Canada's existing mines are both efficient and in a strong position relative to other producers on this continent was revealed during the course of the United States Tariff Commission's hearings in 1953. Concerning themselves with the then depressed condition of the United States lead-zinc mining industry, it was found that "although average labour costs per ton of ore are lower in the United States than in Canada, the metal content is much lower, and hence the cost per unit of lead (and zinc) is much higher in the United States". Also, "much of the Canadian production is derived from large mines and smelting plants capable of producing metal at a lower unit cost than can most United States domestic mines". It was further deduced that the greater portion of Canadian production could be operated profitably at a combined lead-zinc price of 25¢ per pound. It was claimed that American producers, by contrast, needed at least 30¢ in order to remain in business.

Were zinc demand to warrant it, lead mine production would be increased substantially in this country. At-site costs may also remain low. Both the Pine Point deposits in the Northwest Territories and the copper-lead-zinc ores in the Bathurst area of New Brunswick can be recovered in part using open-pit methods. An economic method for transporting the former into Alberta or southeastern British Columbia for treatment has yet to be arranged. Government assistance is being requested in the construction of a railway. In the case of the New Brunswick ores, problems of concentration and processing are still under investigation. No doubt they will be solved. Thus, if the market warrants it, Canada can look forward to one or two major developments. Added to a variety of production originating in smaller properties in British Columbia, Newfoundland, the Yukon, Quebec and Ontario, they offer a potential which, in a comparatively few years, could again make this country the world's second or third largest exporter of lead.

There is some question as to the form which these additional foreign sales will take. Most of the ore originating in western Canada will probably be converted to metal. However, in eastern Canada, there are several obstacles to this which will eventually have to be surmounted. It may not be

immediately possible for any one operator to secure sufficient supplies of concentrates to assure an economic lead refining operation, drawing as he would have to do upon a number of relatively small mines. Freight rates make it uneconomic to ship these concentrates to British Columbia for treatment. Cheap water transport out of the Gulf of St. Lawrence, on the other hand, favours the movement of concentrates to the United States and overseas for refining. Surplus world processing capacity[41] and a ready market for by-products may also tend to delay the erection of primary manufacturing facilities in this part of the country. Hence, it may be some time before Canada returns to the position achieved in the late 1930's during which 85% or more of Canada's exports of lead were in processed form.

Tariffs, import controls and other institutional factors must also be taken into account. Generally, they have tended to limit, or at least postpone, the degree of processing in the source areas. Canadian production will also be susceptible to these same pressures during the next decade or two.

At the present time, the United States levies duties of 0.75¢ and 1.06¢ per pound respectively on ore and metal. Though they continue to provide some protection, this tariff is unlikely to offset the declining competitive position of United States mines. Their output being more or less stabilized, imports will have to look after any increase in that country's total new metal requirements. Additional protection has, of course, been requested. It has been shelved temporarily by the long-term or second stockpiling programme, initiated by the United States government, which itself is in the nature of a market support programme. Whether this continues or whether some form of additional tariff or subsidy to the American industry is provided, the facts appear to be inescapable. In the short run, and especially in slack periods, recourse to quotas, sliding tariffs and subsidies would undoubtedly reduce the advantage of Canadian and other supplies in this market. Depletion and rising costs, meanwhile, are likely to force the American consumer to carry the major share of these imposts over the long period.

While the short-run effect on the Canadian export price is recognized, this sort of behaviour has much more serious consequences in respect to further processing. Heavy investments in smelting and other manufacturing facilities are much more difficult to finance when the market is subject to uncertainties of this kind. From the investors', and particularly from the United States-owned mining companies', point of view it is better to erect these facilities in the United States. Two things would be accomplished thereby. A higher tariff on processed lead would be avoided. Also, material from alternative sources could be treated for such periods of time as import quotas were in effect. Canada, lacking a large commercial market of its own

[41]World processing plant capacity has been estimated at about three million annual tons. Recent production levels have only been around 2.2 million tons. The excess in processing capacity is largely in the United States and Western Europe. International shipments of lead ore have been tripled since the end of World War II. Now they comprise about one-third of the total trade in lead.

or a comparable stockpiling programme, cannot offer a continuity of sale such as might well apply within the United States.

In Europe, tariffs have had less serious consequences in recent years. No duty is set on Commonwealth exports to the United Kingdom and the rate for other countries is low. Spanish and Italian domestic industries have been protected since the early 1930's, but in the major importing countries, free entry is the rule.

(g) *Conclusion*

In world terms, the outlook is one of relative stability. A modest increase in demand can be readily met from existing and new mine production. Some rise in costs may occur, but new areas such as those which can be activated in Canada can, over a period of years, add appreciably to world supplies of new metal.

In respect to markets, the rate of growth is likely to be much slower than that of industry in general. Per capita consumption may even decline. Total requirements are therefore forecast as rising by a modest 20% to 40% over the next quarter century.

Canada's role, meanwhile, may be that of an increasing supplier of world, and particularly North American markets. At one time, this country was responsible for 12% or more of world output. Since 1949 it has dropped below 10%. Over the next decade, its share may improve. For 1965, 11% has been chosen as a provisional figure; and 12% for 1980.

The Canadian market itself is expanding. This may grow at between a 1% and 2% rate over the next quarter century. Exports will account for the balance. Allowing for a substantial lag between the creation of new mine capacity and the erection of primary processing facilities in this country, the following forecast has been prepared.

Table 18

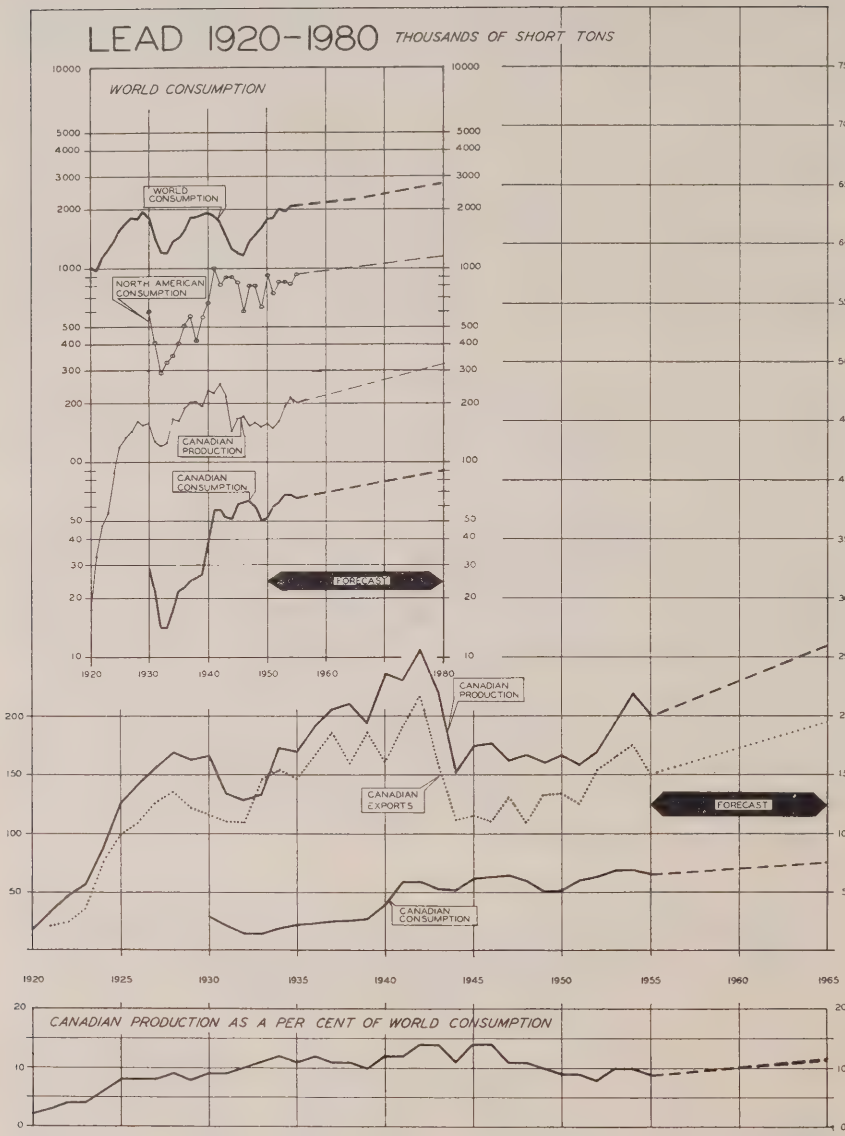
ESTIMATED PRODUCTION, TRADE AND CONSUMPTION OF LEAD IN PRIMARY FORMS

(Canada, 1955, 1965 and 1980)

	Volume in thousands of short tons			Value[a] in millions of 1955 dollars		
	1955	1965	1980	1955	1965	1980
Production	203	260	320	58	67	78
Exports	151	193	237	37	43	50
Domestic consumption[b]	66	75	90	23	24	28

a Assuming a 10% reduction in real price by 1965 and no further change relative to that of all other goods and services from then to 1980. The extent of processing in Canada is also taken to be as at present, namely 60% refined prior to export.

b Including an allowance for some imports and Canadian inventory changes.


LEAD 1920-1980
THOUSANDS OF SHORT TONS
WORLD CONSUMPTION
WORLD CONSUMPTION
NORTH AMERICAN CONSUMPTION
CANADIAN PRODUCTION
CANADIAN CONSUMPTION
FORECAST
CANADIAN PRODUCTION
CANADIAN EXPORTS
FORECAST
CANADIAN CONSUMPTION
CANADIAN PRODUCTION AS A PER CENT OF WORLD CONSUMPTION

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G. *Aluminum*

(a) *Introduction*

Already one of Canada's major metallurgical industries, the production of aluminum promises to become even more important in the years to come. Treating imported materials and competing with other producers in the principal industrial markets of the world, its annual capacity is now approaching the 800,000 ton a year level. For the first time, in 1956, aluminum surpassed copper in value of production and replaced nickel as the leading metal in the nation's export trade.[42]

With the exception of iron, aluminum is the largest tonnage metal in everyday use. Not only does it exceed all other non-ferrous metals individually but its consumption in volume terms is now greater than that of copper, lead and zinc combined. Yet its uses continue to multiply. Roughly doubling every decade since 1900, demand is expected to increase between five and sixfold over the next quarter century.

The underlying causes are many. Industrial designers, confident that aluminum can be made available in adequate quantities, are taking greater advantage of its unique properties of lightness, corrosion resistance, electrical conductivity, good appearance and strength. Such potential substitutes as magnesium, titanium or the plastics either are not available in sufficient quantity or are more difficult to fabricate on a commercial scale. Aluminum's comparative price stability also recommends it to many users of non-ferrous metals. A long-run decline in real cost has also enabled it to move in on a

[42]The 1955 value of production of aluminum ingot in Canada was $281 million; exports in that year were worth some $229 million. A year later the corresponding figures were $300 million and $236 million.

number of the large volume applications formerly served mainly by wood or iron.[43]

Aluminum's success has been due, in no small measure, to improvements in technology at the processing level, product research and aggressive salesmanship. As its volume of sales rose, advantage was taken of numerous economies of scale. Meanwhile, experimentation has led to many new applications, most of which have been retained in periods when other materials have returned to a condition of better supply. This, together with the industry's demonstrated ability to weather such market dislocations as occurred with the falling-off of defence purchases at the end of World War II, provides added grounds for confidence with respect to the future of aluminum.

Important structural changes, meanwhile, are taking place. Until recently, the most efficient aluminum reduction plants continued to be built in remote areas close to ocean transport where large blocks of comparatively cheap hydro-electric power could be allocated permanently to this purpose. Now, however, the industry's views as to what constitutes an ideal smelter location are more flexible. Thermal power, and particularly electricity produced from strip-mined coal close to the main industrial markets, is much more competitive with water-power than it once was. Regional differences in respect to electricity costs, because they are narrowing, are giving a greater weight to other factors including services and transportation. Hence, in circumstances where equipment costs are lower, chemicals and other materials procured more cheaply and products more readily disposed of, sites in or close to major market areas are being viewed with greater favour than has been the case in the past.

In the United States, other influences are also at work. Advantage can be taken of protective tariffs, fast tax write-offs, and a ready supply of capital contingent upon assured long-term defence contracts. Thus, while fundamental economic considerations continue to point, on balance, toward the location of new aluminum smelters in such frontier areas as northern and western Canada, a considerable amount of new capacity has been erected where readily mined coal deposits and markets for primary metal have been found to exist one close by the other.

Overseas the prospects for smelter expansion are less attractive. In Western Europe, fuel suitable for the production of electricity is either too expensive or in relatively short supply. With the exception of a few countries like Norway, Austria and Yugoslavia, most of the remaining water-power potential will be reserved for use in more labour-intensive industries. In the 1960's and 1970's, nuclear energy, if it can be produced competitively with electricity from other sources, will also tend to be fed into existing grids for

[43]Gaining relative to iron, the impact of aluminum on primary iron and steel production has been little noticed. Even if aluminum consumption continues to gain at approximately three times that of iron in the next quarter century, the production of steel will be between 15 and 20 times that of new aluminum metal in 1980.

widespread distribution rather than be allocated to power-hungry uses of this kind. Besides, the demand for electricity in other uses is expected to rise at least as rapidly as on this continent. In other words, a further narrowing in aluminum production costs between Canada and the United States need not necessarily preclude an expansion in Canadian exports, particularly to the United Kingdom, West Germany and the other OEEC countries.

Additional smelting capacity, no doubt, will be built in other parts of the world. Large integrated schemes have frequently been mooted for West Africa, the Belgian Congo and North Borneo. Readily developable hydro-electric resources are available there. In some places suitable reserves of bauxite are to be found close by. This applies to Ghana, French West Africa and Indonesia. Access to markets need not be hampered by lack of hard currency. Producers in such underdeveloped areas, in other words, may be able to escape some of the discrimination which, on this count, may apply against Canadian production.

Militating against such projects are high equipment costs, the expense of having to train local labour, the need to develop basic transportation and other services and, finally, the high interest rates characteristic of investments in areas whose political stability over the long run is open to question.

Canada, meanwhile, has sufficient water-power resources to ensure a considerable expansion in output. Sites ensuring minimum transportation costs are available. So are industrial know-how and the political climate necessary for raising large sums of money at comparatively low rates of return. Indeed, this latter consideration, more than any other, may continue to place Canada among the first two or three of the world's primary aluminum producing nations.

(b) *The Canadian Position*

Currently, Canada's aluminum reduction industry[44] is the second largest in the world. Exceeded only by the United States, it passed that of Germany during the early years of World War II. As recently as 1950 it accounted for over one ton of primary aluminum out of every four produced in all countries combined. At present, its output is in the vicinity of 20% of the world's total.

Interestingly enough the great bulk of its output, about 85% is exported. At present these shipments, comprising roughly three-quarters of the world's international trade in light metals, make up about 5% of Canadian exports of all goods and services. Meanwhile, every ton of bauxite ore and processed alumina is brought in from sources in the Caribbean and French West Africa; natural cryolite from Greenland. Such is the industry's size that

[44]To date, the aluminum industry has invested approximately $1 billion in Canada.

these, together, account for about 10% of Canada's total imports of industrial minerals.

Although the processing of this ore and its final reduction to metal has brought into being a highly capital-intensive industry, some 25,000 workers now find direct employment in the primary processing and semi-fabrication of aluminum in Canada. Even more important than the employment opportunities which it creates has been the opening up of new industrial areas and the exceptionally large outlay on construction and purchases from the other suppliers of capital goods, which have paralleled the erection of all this aluminum smelting capacity.

(c) *Background of the Industry*

Although aluminum is one of the most abundant metals in the earth's crust (about 8% of all material to a depth of ten miles), it has not, until comparatively recently, been readily separable from its natural state. First produced commercially in France in 1854, it remained a curiosity until the problems associated with the generation of electricity were resolved in the 1880's. Then, with the invention of the Bayer process for extracting alumina from bauxite and, at about the same time, the Hall-Héroult process for the reduction of alumina to metal, quantity production became possible. With refinement and a result of increases in the scale of production, the price of aluminum fell. It dropped from around $1.50 a pound in the 1890's to 15¢ during World War II. Production rose slowly at first, then with gathering momentum. Measured in the thousands of tons around the turn of the century, world output first exceeded two million tons a year in 1943. In 1955, it was in the order of 3.2 million short tons.[45]

Despite a continually expanding market, aluminum has had its setbacks. The recession of the early 1930's served to depress sales for a time. Shortly afterward, the exigencies of defence called for an unprecedented effort. World output more than trebled between 1939 and 1943. Then, with the cessation of defence buying and with the withdrawal or destruction of plants in Germany and the Far East, it fell back abruptly to its prewar level. Since then, the rapid development of commercial applications, superimposed since Korea upon a defence production programme of considerable magnitude, has caused output to exceed all previous records.

Consumption, while it has sometimes lagged behind production, has shown a similar long-term tendency to move upward. Initially restricted by high capital costs, complicated technology and a lack of knowledge as to adequate fabricating and alloying techniques, demand for this metal has risen at an average annual rate of 10% since 1900. First accepted for the manufacture of cooking utensils and decorative purposes, it has since been

[45]SOURCE: American Bureau of Metal Statistics, New York, N.Y.

employed widely in (and even made possible) such entirely new large-scale industries as aircraft production and the manufacture of certain types of electrical equipment.

War and the preparation for war have helped to break down a number of barriers. Not only has it provided much of the necessary plant but it has also resulted in a measure of experience which would otherwise have taken years, if not decades, to emerge. Postwar, there has been the added incentive to put idle capacity to work. This, with the more adventurous spirit which is often characteristic of the newer industries, has helped aluminum to become one of the leading structural materials.

Before an assessment of its longer-run market prospects is attempted, a brief resumé of international developments over the past quarter century may be in order. Following the Depression of the 1930's, production first recovered in the German and Japanese controlled areas (Austria, Hungary, Formosa, Korea and Manchuria). Later, it was followed by new additions to capacity in the United Kingdom, Russia, and particularly, in North America during the course of World War II. Much of this capacity was uneconomic in the truly commercial sense. Subsequently, numerous plants were either closed down, converted to other uses, or dismantled in the United Kingdom and in the United States. Yet, by 1950, aided by a steady rise in civilian requirements, world output was approximately double its 1946 low of 870,000 tons.

The Korean emergency, by superimposing military requirements, called for the erection of additional capacity. This has been forthcoming in the United States especially, although new facilities have also been installed in Europe, Canada and Australia. In 1955, output in the United States was approximately double 1950 production; capacity was 110% higher. In order to accomplish this, a number of new projects were launched in the United States, the majority located along the Gulf coast. With only part of the new Kitimat plant in operation, output in Canada increased by more than 50% over its 1950 level. In other countries, more of the expansion came as a result of rehabilitating old smelters or from additions to existing plants.

Germany is again one of Western Europe's largest producers of primary metal. Production in Austria has trebled and France and Japan managed to double ingot production between 1950 and 1954. By 1955, Norway's capacity was double that of five years earlier. Meanwhile, the capacity of plants in Russia has risen in even more spectacular fashion. Close to 500,000 tons of capacity are believed to be operating there.[46] Poland and Czechoslovakia have become manufacturers of aluminum ingot. Elsewhere in the Eastern Hemisphere other facilities are believed to be under construction.

[46]SOURCE: American Bureau of Metal Statistics, New York, N.Y.

(d) *Long-Term Market Trends*

The steadily mounting demand for aluminum is contingent, in no small measure, upon the physical and chemical properties of this metal and its alloys. Briefly stated they are:

(i) aluminum has a high strength-to-weight ratio, particularly when alloyed with such other metals as copper, magnesium, silicon, manganese, and zinc. Hence, it is being employed to advantage in structural applications where the elimination of dead weight is an important consideration;

(ii) the electrical resistance of an aluminum conductor is about half that of a copper conductor of equal weight and length. For this reason, it has displaced the latter metal in transmission lines and is challenging its position in the insulated conductor field and in the manufacture of machinery and equipment;

(iii) aluminum, because it resists corrosion by atmospheric action, is being employed much more widely by the construction industry. Greater advantage is also being taken of its corrosion resistent properties by the chemical industry. The non-toxic nature of its products also permits its incorporation in food processing and handling equipment as well as in the manufacture of containers of many descriptions, including the wide field of food wrappings;

(iv) aluminum's high reflectivity of light and radiant energy has made it a preferred material for laggings in both high and low temperature fields; and

(v) it is one of the most workable of metals. Aluminum can be rolled, extruded, forged, spun, drawn and machined easily. Also, because it can be worked to very fine tolerance, it has become available in an ever widening range of fabricated forms.

In addition to quality, another major determinant of demand for aluminum is price. Despite the inflation of the past decade it is currently being offered at a price only about 20% higher than the level at which it was quoted in 1939. Its principal competitors, meanwhile, have experienced much greater price increases. Copper, for example, is some 250% higher; lead, 200% higher; zinc, 170% higher; nickel, 110% higher; tin, 100% higher; and steel billets 125% above the immediate prewar level.

Viewed over a longer period, these differences appear even more striking. Since 1945, the major ferrous and non-ferrous metals have consistently sold at prices 60% to 100%, or more, above those being quoted in the mid-1920's.

Aluminum metal is being offered, even today, at a price below its 1922-26 level. As recently as 1950, it was 40% below the average of 30 years ago.

Of comparable importance has been the absence, in the case of aluminum, of the sudden and sometimes wide fluctuations in price which have characterized most other metals. This tendency to greater stability is by no means accidental. This uniform behaviour can be traced mainly to:

(i) the absence of marginal producers in an industry which requires specialized know-how and vast capital resources; and

(ii) the apparent realization by the major aluminum producers that stable prices offer the greatest hope for holding old markets and for developing new ones.

From what has been said in the introductory section to this chapter, it is apparent that various of the other large volume metals are increasing in cost relative to aluminum. (See chart, Aluminum and Competitive Materials—Relative Prices for Equal Volumes—Annual Averages, 1925-55.) Copper costs four to five times, and lead up to three times, more than an equal volume of aluminum. Already, nearly all long distance electrical cable is of aluminum rather than copper, and further invasion of the electrical field is unavoidable. Most lead is used for its chemical properties, but the main structural use of covering submarine cable is being taken over in part by aluminum and plastics.

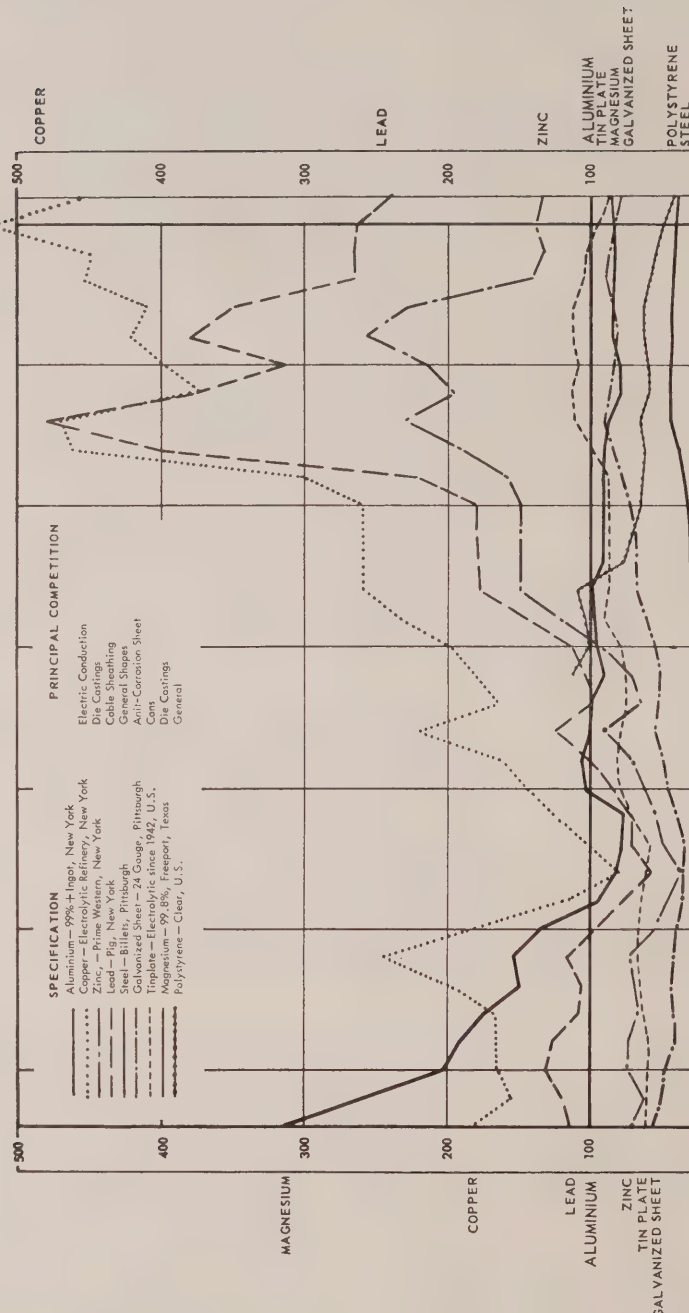
Zinc is, at present, approximately 50% more costly than aluminum, volume for volume, and is, therefore, vulnerable to substitution by aluminum in die casting, a fast growing market currently using zinc at a weight ratio of 2 to 1 over aluminum; per volume, aluminum already covers well over 50% of the die casting market and its use, especially in the automotive industry, is fast expanding. Sheet steel galvanized with zinc has a 20% advantage in price over aluminum sheet, but aluminum is lighter, is a better reflector and cannot flake as galvanized zinc may under certain conditions. Aluminized steel sheet is also gaining in popularity.

Ordinary carbon steel is maintaining its relative position at just over 60% of the price of an equal volume of aluminum, hence aluminum is not likely to replace steel for general structural purposes. However, in the past, the size of the steel industry has permitted more efficient single purpose fabricating operations; aluminum is just now entering this phase. Such improved techniques as continuous rolling mills, impact extruding, continuous casting, and roll-forming processes for sheets and rods, welded tubing and continuous anodizing are already being used and others will follow. This, together with its natural advantage of light weight, resistance to corrosion and pleasing appearance will continue to improve aluminum's competitive position in a number of steel's traditional outlets.

ALUMINIUM AND COMPETITIVE MATERIALS – RELATIVE PRICES FOR EQUAL VOLUMES

ANNUAL AVERAGES 1925 TO 1956

ALUMINIUM = 100



Tinplate, with the much thinner coatings made possible by the electrolytic process, has a 20% to 30% advantage in price over aluminum sheet. Yet cans made of aluminum are already preferable for certain applications. Corrosion resistance and other qualitative features if supported by a more favourable price relationship will encourage wider usage in the canning industry of the future.

On the other hand, aluminum is already subject to competition from magnesium and plastics, and, in the near future, titanium may compete in several fields. Magnesium is no more expensive than aluminum, volume for volume; it can be easily worked; and there is an easily accessible and inexhaustible supply in sea water and dolomite. It may be substituted for aluminum and other metals in castings and most rolled products. Of the many types of plastics, polystyrene is but 38% by weight of aluminum and, by volume, costs but 60% as much. Plastics lack the strength and versatility of metal but have already found wide acceptance. Aluminum and other metals face continuing and perhaps intensified competition from plastics in castings, in foil and sheet, in smallware and many other products.

Titanium is at the threshold of commercial development. Solutions to the present difficulties in extracting titanium from its ore and in its fabrication are in the offing with a consequent substantial drop in price from the present level of around $2.75 a pound. As this takes place titanium will offer increasing competition to aluminum in the aircraft industry and to aluminum and stainless steel in many other fields, especially where high corrosion resistance or a high strength-to-weight ratio at elevated service temperatures is essential.

The loss of at least part of the aircraft market to these newer metals will have its compensating aspects. Though aircraft production has been the prime mover, particularly during World War II and since 1950, it is by nature extremely erratic, ranging from close to 90% to as low as 5% of total demand. The early obsolescence of military aircraft also tends to leave in its trail a ready supply of usable scrap. The effect of this on new metal production, unfortunately, has been greatest when sales, over-all, were tending to subside. In future, with these defence associated demands taking less and less of the total, the primary producers will be less subject to these sudden unwelcome invasions of their market by secondary metal.

Secondary aluminum from marketed sources constitutes approximately one-fifth of the aluminum available for consumption by foundries and semi-fabricators, and dissipative uses on this continent. Currently, new scrap accounts for more than 15% of primary consumption. Immediately after World War II, when this metal was first being introduced on a large scale, it was more in the order of 45%. The quantity of old scrap available for treatment for metal recovery has shown no consistent trend. In 1947, when

a large quantity of aluminum was recovered from obsolete and discarded aircraft and other defence equipment, metal recovery from old scrap rose to 29% of apparent primary consumption, compared with 5% in 1953.

Secondary production is also an important supply factor in Europe. Scrap usage which climbed rapidly after World War II still accounts for about 30% of the aluminum consumption of the United Kingdom and West Germany.

With each passing year new consumer and industrial demands are being felt. Not only are they softening the impact of the decisions relating to military procurement; another result has been a geographic shift in sales toward countries whose programmes of capital investment are showing a relative increase.

A 1953 survey by Aluminium Limited, Montreal, shows end-use, by region and by major trade classification, to have been approximately as shown in Table 19.

Table 19

PATTERN OF ALUMINUM CONSUMPTION

(in per cent)

End use	Free world	U.S.	Canada	Europe
Transportation	28	28	21	30
Building and construction	16	19	33	7
Electrical industry	12	10	18	15
Household and commercial	14	13	7	14
Canning and packaging	8	7	5	10
Food and farming	2	2	2	2
Other industries and unclassified	20	21	14	22
Total	100	100	100	100

Tracing this series back over time, the recent gains which have been made in respect to construction appear noteworthy. In the largest category, transportation, use in the automotive and railroad industries and in shipbuilding also shows considerable promise. The same, generally speaking, is true of electrical apparatus and packaging. Since the controlling factor in any further projection of demand is civilian consumption, the following detailed observations as to end-use are pertinent to an over-all forecast of market requirements.

In respect to *construction,* aluminum on this continent has already captured half of the window business. It is also being used extensively in the manufacture of doors, roofing ducts, and moulding materials. A growing number of offices and industrial buildings are employing this metal in the form of exterior containing walls. Coloured exterior and porcelain enamelled panels also show promise for future use in hospitals and schools. The potential demand for prefabricated housing is consider-

able, particularly in tropical and semi-tropical countries lacking transportable building materials. Free world consumption under the general heading of construction was estimated to be in the order of 550,000 tons in 1955. By 1980, it may have expanded four or five times over.

Many forms of *transportation equipment* now employ aluminum in place of heavier steel components. This replacement has particularly taken place with respect to buses and trailers. However, there is considerable scope for substitution in trucks and railroad passenger and freight cars. The automobile industry may become a leading consumer. Aluminum pistons are now almost universally used and there is a growing use in automatic transmissions, instrument panels, trim and small components. In the future, aluminum may replace chrome in automobile trim, copper in radiator cores and electrical harness, and grey iron in engine components. Average aluminum content in 1957 models increased to 38 pounds from 30 pounds in 1955; in the future, a reasonable estimate of use would be 75 pounds per car in 1960 and over 200 pounds per car by 1980. At the 1955 United States production rate of eight million passenger units a year, this means consumption of 300,000 tons annually by 1960 rising to almost one million tons by 1980.

In the *electrical industry,* aluminum finds a major and growing market in the transmission and distribution of electricity and the manufacture of electrical equipment, motors and appliances. For many years, all high-tension transmission lines have been aluminum. In recent years, use has extended to busbars and the broad field of low-tension transmission. Recent developments indicate the use of anodized bare aluminum wire in place of insulated wire for motor windings. In all these applications, the main competitor is copper. Yet copper, because of recurring shortages and uncertainties as to price, tends to be used more sparingly. In general this has been true even in applications where copper's physical and chemical properties would otherwise allow it to be employed to advantage.

Elsewhere, it has been estimated that the consumption, worldwide, of electricity will continue to increase at around 7% per annum. New copper production, forecast at a 4% yearly rate, will probably fall short of meeting the requirements associated with the electrical equipment producing industries. Hence, aluminum will be required in increasing amounts in the production of insulated power cables, household wire and telephone wire. Free world use in this connection may approximate 820,000 tons in 1960. It could be in the order of 1.5 million tons 25 years hence.

The use of aluminum for irrigation and industrial *pipe* is increasing rapidly; during 1955, the free world consumption for portable sprinkler irrigation was 42,000 tons, an increase of 22% over 1954. Rapid expansion of this market may be expected in North America, South America and Asia,

and this use will reach an estimated 100,000 tons a year by 1960 and perhaps double that figure by 1980. Industrial pipe for oil production and for other industries was introduced in 1955. Its application is in its infancy but a rapid growth to a consumption of about 50,000 tons by 1960 is probable and triple that amount by 1980.

One of the fastest growing uses is for *canning and packaging*. Aluminum foil is now used in the entire field of food, household and industrial packaging and there is a large and growing market in the frozen food and bakery trade that will probably double present consumption in the field within a few years. In the canning industry, in which five million tons of tinplate are used annually, aluminum has been making a substantial entry, particularly in Europe. It is now used in the canning of such products as lubricating oil, fish, beer, condensed milk and other types of food as well as in aerosol containers. This evidence reinforced by other possibilities which are presently under investigation suggest that, by 1980, world demand in container applications might be in excess of 500,000 tons a year.

(e) *Projected World Demand*

Our own studies indicate four separate projections to 1980 relating to free world requirements. They are based on:

(i) the historical growth rates of primary aluminum consumption;

(ii) a forecast of future steel requirements and the changing ratio of aluminum consumption relative to that of steel;

(iii) the industry's surveys reporting future regional market requirements; and

(iv) the rate at which resources (including low-cost electric power, capital and specialized equipment) can be made available for the production of aluminum metal.

Described independently, they yield results which vary by more than two to one. The higher projections have been rejected. In doing so, there is an inference that aluminum is reaching a stage when past historical rates of growth in demand can no longer be held to apply. Yet additions to capacity far in excess of those achieved to date must be realized if the attainment of the still considerable upward trend in sales forecast in this report is to be realized.

(i) *Historical approach*

To establish a basis for projecting demand, a study was undertaken to determine the historical growth rates of primary aluminum consumption. Pertaining to the periods mentioned, these were established as follows:

United States, 11.6% since 1900; Western Europe, 9.3% since 1900; Canada, 10% since 1929; and, for the world as a whole, a long-run growth rate since the turn of the century of closer to 11% annually.

Were demand assumed to continue rising at this rate world consumption would approximately triple to nine million tons annually over the next decade and reach 45 million tons a year by 1980. That this expectation is unreasonably high is apparent from an examination of presently projected additions to capacity. According to publicly announced plans, the building of new plant will add about 60% to the world's output by 1960. This, expressed in percentage terms, is equivalent to a yearly rate of only about 9%. Thus, it appears that, using a purely historical approach, our projection for 1965 would almost certainly be in excess of production. A figure arrived at in this way for 1980 is even more likely to be above the level of output actually achieved during the next quarter century.

(ii) *Aluminum vs. steel*

In order to establish a relationship with steel, primary aluminum consumption was taken as a percentage of steel ingot output for each of the years from 1900 onward. A power curve of second degree revealed that, each year without exception the demand for aluminum rose relative to that of steel. Around the turn of the century, it was in the vicinity of 0.02% of steel ingot output. By 1955, it had risen to 1.44%. Using a 3% per annum growth rate for steel and projecting aluminum requirements by this method results in a relationship of 6.8% by 1980.

Listed by area, this exercise resulted in the demand appraisal outlined in Table 20.

Table 20

PROJECTION OF DEMAND BASED ON RELATIONSHIP IN GROWTH WITH STEEL INGOT PRODUCTION

(in thousands of short tons)

Area	Consumption 1955	Historical growth percentage	Growth adjusted to relationship with steel (%)	Estimated demand 1965	Estimated demand 1980
U.S.	1,750	11.6	9.0	4,100	15,000
Europe	910	9.3	7.2	1,800	5,000
Canada	77	10.0	7.7	180	550
U.S.S.R.	365	10.0	8.7	840	3,000
Other	108	10.0	7.7	225	700
World	3,200	10.8	8.3	7,145	24,250

The end result is substantially lower than that arrived at earlier. Were aluminum in relatively free supply, free world sales might maintain the long-term statistical growth rate well into the 1960's. Thereafter, as it begins to

encounter more intensive competition from iron in the latter's lower-cost uses, its markets may begin to drop off toward (or even fall below) the annual twenty-fifth year requirement of 24 million tons indicated by the aluminum-steel relationship reported in the accompanying table. For the total period up to 1980, this would be the equivalent of an annual average growth rate of 8.33%.

(iii) *Regional analysis*

Currently, the demand for new metal is rising more rapidly in one part of the world as compared with another.[47] For example, industry studies made available to the Commission point toward a 7% per annum increase in consumption in the Western Hemisphere between now and the early 1960's. The regional forecasts for Western Europe have been, generally, higher. These, on the average, were in excess of 10% a year. In respect to Africa and the Middle East, a figure of 12% was envisaged. In the Pacific area, and this includes Japan, India, Pakistan, the Philippines and Australia, 12% was also considered to be an approximate measure of future requirements. In total and taking into account the different intensities in use, this points—in the short term at least—to an over-all world increase in demand for primary metal in the order of 8% yearly.[48]

(iv) *Supply vs. demand*

While the price of aluminum metal may remain comparatively stable (or even decline) relative to that of other goods and services, supply factors may tend to set an upper limit on its availability. Physically speaking, the resources necessary to double its production with each ensuing decade are available. Yet their mobilization will also take time and money. Each year, as the annual increase in smelter capacity becomes more impressive, delays due to temporary market uncertainties, holdups in construction material and equipment deliveries, and problems associated with raising capital will become more difficult to resolve. Eventually the task of raising money itself may become such as to cause a slowdown in the yearly rates of increase in world primary aluminum output.

[47]Distribution by country: As with all industrial materials, intensity of use varies widely, especially at the primary ingot stage (which does not allow for subsequent trade in finished goods). However, the fabrication of aluminum, because of its workability and versatility, has made substantial progress in some less industrialized nations.

Nevertheless, over 80% of ingot consumption is in North America and Western Europe. A shift in relative importance from Europe to America is evident since the prewar period. It parallels the shift in production but is less extreme—and leaves Europe even more dependent on imports. In most countries or regions, consumption has increased 5 to 12 times since prewar—except in parts of continental Europe and in Japan. Only in Germany and Japan is it still below wartime levels.

[48]In substantiating these forecasts and drawing conclusions for the more remote future, further mention should be made of the changing national and per capita rates of consumption by country. Today, the U.S. alone accounts for more than half of the total world consumption. Its share, however, is dropping. It may fall from around two-thirds in 1953 to around 55% in 1960. This, in part, is a reflection of the estimated doubling of demand in the United Kingdom, Western Germany, and France. Forecast increases for Canada and the United States, on the other hand, are more in the order of 60%

As far as raw materials are concerned, there is little to worry about.[49] Bauxite reserves sufficient to support present world production for half a century have already been proven. Additional resources are also under investigation in the Caribbean area, in West Africa and in various places in the Far East. Their geopraphical dispersal also is such that export embargoes applying to bauxite or alumina are unlikely to be particularly effective against processing countries like Canada. The manufacture of aluminum ingot, in other words, will continue to expand without undue hindrance in centres where such factors of production as equipment, other process materials and electrical energy can be assembled at minimum over-all cost.

Although further economies may be realized per unit of product, new power generating plant with a capacity comparable to the projected output of new metal will be required. Hydro-electric resources sufficient to meet the greater part of these needs appear to be available in countries like Canada and Norway. Thermal power produced from strip-mined coal or natural gas is also becoming more competitive in the United States, Australia, Africa and certain Asiatic countries. Nuclear energy, by 1975 or thereabouts, may also make primary aluminum production economic in Western Europe. One must therefore look beyond mineral and power availabilities if he is to discover influences which are likely to cause a progressive deceleration of aluminum production.

The accumulation of the construction materials and equipment necessary to execute such a programme may present certain difficulties. Already heavily taxed by the continuing demands made on them by the power utilities, producers of some of these goods may be hard put to keep up with the needs of a burgeoning aluminum industry. More generating plants will be required. Additional smelting and other processing facilities will have to be erected. New transportation facilities in the form of new ore carriers, handling equipment, docks, etc., will also involve a substantial building programme. Delays introduced by defence and priorities or by the competition from other investment projects may, at times, serve to hold up additions to capacity which demand considerations alone would have justified earlier.

Finally, there is the question of investment capital. In some respects the problem of increasing the world's output of primary aluminum is akin to that of expanding the amount of electric power generated for other purposes. Both the aluminum industry and the electric power utilities are capital-intensive. Both depend upon the mobilization of considerable sums of money well in advance of the first offering of their output for sale. Because demand is

[49] Known world reserves of usable ore are large—well over 100 years' supply at the current rate of mining—and are being discovered at a rapid rate. Four of the five largest reserves, excluding Hungary in the Soviet sphere, have only in recent years become known as to their great extent and, until very recently, have hardly been exploited at all. They are in Jamaica, French West Africa, Ghana and Brazil. Thus, there is no cause for concern over ore reserves except in the sense that major metal producers are not domestically self-sufficient. In addition to published reserves, it is estimated that known deposits of low-grade bauxite and alumina clays are several times greater than the totals of commercial ore.

likely to be persistent and costs manageable, funds sufficient to ensure steady rate of expansion may be available to primary aluminum producers and electric power companies alike. Both will therefore be in a position to divert a sizable part of their earnings, year in and year out, toward the creation of new productive facilities without seriously undermining their ability to raise money or pay increased dividends in later years.

Yet they differ in certain respects. Most power utilities, because of their exclusive franchise position, enjoy a monopoly in their market area. Few power companies are dependent to any degree on export sales. Unlike the aluminum companies, outside the world's main consuming areas they are rarely subject to the type of dislocation which can result from currency restrictions, increased tariff protection, import quotas and other hindrance to international trade. Historically, electric power consumption has also been less likely to level off during periods when defence orders were being curtailed or when business activity was on the decline. In this connection, the outlook of the aluminum and chemical industries have more in common.

This being the case, additions to primary aluminum capacity may eventually lag behind, rather than lead, the 7% rate normally associated with the growth in world output of electric power. Toward the end of the forecast period they may drop back to around the 6% a year expansion indicated in *The Canadian Chemical Industry* as relevant to chemical sales. Primary aluminum production, assuming an 8% rate over the next decade and a 6% per annum growth thereafter, results in a world output of approximately 17.5 million tons in 1980. A range beginning at 15 million and rising to 20 million tons a year is even more descriptive of the likely level of world primary aluminum output 25 years hence.

(f) *Trade and Tariffs*

In the case of aluminum, the great bulk of trade is in the form of ore rather than metal. This is in direct contrast to the trend in the older non-ferrous metal industries, where more refining is taking place in the less developed mining countries, and ore is being replaced by metal in shipments to the major consuming countries. This aluminum pattern may be partly the result of the influence of cheap power, which is not usually found close to bauxite, but also results from the importance attached to domestic plant location by the major military and industrial powers.

However, the recognition of growing costs of production in the United States and most parts of Europe, and the building or planning of alumina or aluminum plants in Jamaica, British Guiana, Brazil, Ghana and French West Africa already indicate a possible change in the past pattern of plant location. This may parallel, to a certain degree, developments in other metals and may anticipate a rising political consciousness in the bauxite producing area.

(i) *Bauxite trade*

While Arkansas, France, Italy, India, Brazil, Yugoslavia and the Soviet bloc possess both bauxite mines and aluminum plants, nevertheless about 75% of free world bauxite production enters into international trade. A small but increasing proportion enters into trade as alumina, with France, Germany and Canada (Quebec) shipping to Norway, Sweden and Switzerland, and now Jamaica to British Columbia, Norway and Sweden. If Hungary and Russia are considered as one economic unit, the Soviet bloc is self-sufficient and takes no part in international exchange at their current rate of consumption.

In 1955, the principal trade movements were from Surinam and Jamaica to the United States, accounting for 50% of all trade; from British Guiana, Jamaica and French West Africa to Canada covering 27%; and, in Europe, from Yugoslavia, France and Greece to Germany, Britain, Italy and Norway. Japan and, to a lesser extent, Formosa now are supplied by Indonesia and the reopened Malayan mines. The United Kingdom also imports from Ghana.

(ii) *Aluminum trade*

Aluminum exports are dominated by Canada, the source of 70% of total shipments in 1955 and probably over 75% of net exports. The next largest exporters are Norway which supplies over 8% of total exports and Austria, about 5%.

Over 75% of total imports are received by the United Kingdom and the United States. However, the distribution between the two countries has varied in recent years. Until 1949, and again in 1951 and 1952, the United Kingdom was the major importer (excepting World War II). But, in 1950, the intake of the United States was the larger and, in 1955, nearly half of world exports went to the United Kingdom and 30% to the United States. Although these fluctuations may continue, it is likely that United States imports will remain much higher than before the Korean outbreak. At the same time, United Kingdom import requirements will remain large and, in the next few years, the proportion of imports of the two countries may be quite similar to the 1955 pattern. Canada is, of course, the major foreign supplier to both countries.

Increasing Norwegian production will probably help supply a growing deficit in continental Europe. New capacity in Brazil, Ghana, Australia and Japan may be adequate to meet most of the needs of Latin America, Africa and the Far East. Canadian producers, playing a supplementary role in these regions may continue to dominate the world's inter-continental trade in aluminum ingot.

(iii) *Tariffs*

In general, tariffs have not been a very important factor in the sellers' market of the past 15 years. Moreover, the relatively small amount of aluminum metal entering into international trade reduces the influence of the tariffs structure except in the case of Canada's exports to the United States and to the United Kingdom. In fact, many of the objectives of tariffs—partial self-sufficiency, protected domestic investment, etc.—have been achieved as far as practically possible by such means as exchange controls and import quotas, or direct internal subsidies.

Prior to 1914, the United States had a protective tariff of 8¢ and later 7¢ a pound. This was lowered in 1922 to 5¢ and, in 1930, to 4¢. The output of Arvida after 1926 presented a real threat to European producers and, with the Depression, resulted in a series of protective tariffs in France, Switzerland and Germany. At the same time, the United Kingdom adopted a temporary 10% tariff on metal from outside the Commonwealth. Meanwhile, cartel agreements and defence purchases were also effective. Thus, by agreement and otherwise, the principal international trade was between Canada and Japan in the 1930's and between Canada and the United Kingdom in the years immediately after World War II.

The United States tariff on primary metal is now 1.4¢ a pound.[50] Since Canadian producers absorb this charge and sell in the United States at the market price, there is a differential (with allowance for exchange rates) between United States and Canadian prices. Ingot producers in the United States (and most other countries) have integrated and associated fabricating facilities about equal to primary production and have little reason to fear competition in ingot. A 2.8¢ per pound United States tariff on semi-fabricated products protects[51] them at the next stage.

The physical need for metal imports into the United Kingdom precludes the imposition of heavy tariffs at the present time. Proposed developments in the sterling area (Africa) may change this situation in the future.

(g) *Market Control*

A high degree of concentrated corporate ownership still exists in the primary aluminum industry.

Although there was legal separation of the foreign properties of the Aluminum Company of America (ALCOA) from the United States holdings as far back as 1928, majority stock control of both ALCOA and Aluminium Limited, the new Canadian company, remained in the hands of three or four owners until 1950. At that time, the United States courts ordered the separa-

[50]To be further reduced to 1.25¢ by 1958.
[51]Scheduled to be reduced to 2.5¢ a pound by 1958.

tion of ownership and placed the stock to be divested in trusteeship until sold.

No collusion in management between the two companies was proven. However, the size and influence of the two firms was in itself enough to trouble the United States anti-trust authorities. United States government action was not limited to the courts. The two competitors, Reynolds and Kaiser, have virtually been created since 1940 by such devices as government contracts, financial concessions, easy terms for the better wartime plants and access to government ore stockpiles. ALCOA engineered and operated most of the World War II plants and at the end of the war the most economic plants were turned over to competitors. Moreover, ALCOA was induced to throw in the rights to at least one very complex processing method for a certain type of American bauxite.

ALCOA was the sole North American primary ingot producer until 1928 and the only United States producer until 1940. Even during World War II, it operated 96% of the alumina capacity and 91% of the aluminum capacity of the United States, although many plants were owned by the government. During this period, North American production jumped from 36% to 69% of world output. Practically all of this had stemmed from the original company, ALCOA.

But today, rather than controlling all North American production and over two-thirds of world output, ALCOA accounts for less than half of United States output, one-third of North American and just over one-fifth of world supply. During the years 1948-51, the plants of the Aluminum Co. of Canada (ALCAN, principal subsidiary of Aluminium Limited) produced more ingot than ALCOA, a situation that is likely to recur when the Kitimat project reaches capacity. Reynolds and Kaiser, the two other major United States producers, together passed ALCAN in volume of output in 1953 and currently rank as the third and fourth largest primary aluminum manufacturing concerns on this continent.[52]

Four operating companies control nearly 70% of total world production and 75% of free world production. In addition to Canadian plants, Aluminium Limited owns, wholly or in part, reduction plants in Sweden, Norway, Italy, Brazil, Japan, and India with a current output of about 80,000 tons annually.

Of the remaining 30% of aluminum output more than one-third is under Communist state control.

France and Germany each has one large and one smaller producer. All British output is by one company, and in both Switzerland and Austria one

[52]Some indication of the relative size of this Canadian industry can be obtained through a comparison with the dollar value of sales of the major United States producers. Aluminium Limited's total turnover is approximately equal to that of Reynolds, greater than Kaiser and less than one-half of ALCOA's in 1954. Gross assets show that Aluminium Limited is second to ALCOA and approximately twice that of either Reynolds or Kaiser.

firm predominates. In Norway, there is one government-owned company, in Italy two firms, and in Sweden none other than partially-owned subsidiaries of Aluminium Limited.

In summary, four concerns control two-thirds of current world production; 5 control 81%; 8 control 90%; and 14 control about 98%.

Future developments will be sponsored largely by this group. Aluminium Limited and the British producer, British Aluminium Ltd., have a joint interest in the proposed Ghana project. French plans in Africa and American plans for Alaska are also largely contingent upon decisions which will be made by existing French and United States firms.

(h) *Possibilities for Future Expansion in Canada*

World consumption is expected to go on rising at a rate well in excess of that for all other metals. Forecast at between 7% and 9% per annum over the next quarter century, it could result in a five to sevenfold multiplication in output between now and 1980.

The more important concern, however, is the contribution which Canadian sources will be able to make. In the years prior to 1940, smelters in this country produced, on the average, something like 10% of the world's needs for primary metal. Much has happened since then. Since 1943, with the impetus given to the construction of new capacity by defence contracts in this country and the withdrawal or destruction of a great deal of plant in Germany and the Far East, the Canadian industry has moved ahead of many of its competitors. As recently as 1950, Canada supplied 25% of world demand. The question now is, "Will this country be able to maintain its present share of the world's market for this metal?" There can be no doubt that the power resources are available. Yet other cost factors, market shifts and government policies with respect to trade may still lead to a progressive diminution of Canada's role of a major producer of primary metal.

With the industry entering a more mature phase, there is less likelihood of process and other technological improvements bringing about a marked change in component costs. Outlays on raw materials, labour, and electric power, in other words, may be less susceptible to change. Carrying charges, because they will be influenced by inflation and such factors as plant life expectancy, will be less favourable to market oriented projects than a cursory examination of thermal power based facilities might otherwise indicate.

Some idea of the weighting of these various costs is given by a rough breakdown based on recent Canadian experience:[53]

[53]Generally, it has been assumed that, in addition to 18,000 kilowatt-hours of electricity, the following are required to make one ton of aluminum ingot: four tons of high grade bauxite, 1,200 pounds of carbon, 200 pounds of fluorspar and cryolite, and substantial amounts of caustic soda, coal, pitch and fuel oil.

(1)	Cost of bauxite (including transportation)	20%
(2)	Direct labour cost	15%
(3)	Other raw materials (including transportation)	20%
(4)	Electric power	15%
(5)	Indirect and overhead costs	30%
	Total	100%

Thus, it would appear that processing components (3 plus 4) make up more than one-third of the final cost of aluminum ingot. Perhaps even more significant is that indirect costs (5) and power costs (4) (which facilities in Canada are almost entirely company-owned and capitalized) account for nearly one-half of the final cost of aluminum. The lesser importance of direct labour charges and ore procurement costs is obvious.

Costs in the United States were, until 1950, generally considered to be substantially higher than in eastern Canada. Just prior to the Korean war, United States power costs were three times higher than in Canada and alumina was less expensive at Arvida, Quebec, because no long rail haul to the reduction plant was involved. Little difference would be expected in bauxite, other raw materials, administrative and labour costs. A number of the new American plants (being located on the Gulf coast) have, however, eliminated the long alumina haul and are now relying on long-term, low-priced natural gas contracts to meet their energy needs. Now, with new contract gas prices at a substantially higher level, the tendency is to go to coal. Strip-mined lignite from the Gulf coast area and large volume production in the Ohio Valley, closer to the principal North American markets for aluminum products, promise to provide electricity for as little as three and one-half or four mills per kilowatt-hour.[54]

From this, it would appear that Canada's historical advantage in power and raw material transportation costs is being progressively reduced—that is, relative to the producers in the United States. "Other materials" and capital costs, meanwhile, are continuing to be the higher of the two. Thus, it would appear that, with the added penalty of having to overcome the United States tariff, the Canadian industry will have no easy task in gaining a larger share of the total United States market for new metal.

Outside North America, competition will be much less acute. Even with the advent of nuclear energy, electricity is likely to be much more expensive in the highly industrialized countries. The same, doubtless, will be true of certain "other materials" including coal, fuel oil, petroleum coke and fluorspar. Bauxite will be at least equally expensive and hence the advantages of lower wages, and perhaps of capital costs, will be more than offset

[54]Hydro power delivered at tidewater in Canada from new plants is presently being offered at around three mills/kilowatt-hour.

by the North American economies stemming from the cheaper energy and materials mentioned previously.

Of course, the hydro-electric developments similar to those which have already been established in Canada will be launched elsewhere. During the next ten years, it may well be that such facilities will have been constructed not only in Ghana, but elsewhere in West Africa. Smelters employing water-power and drawing on nearby deposits of bauxite may also be under construction in one or more places in the Far East including North Borneo. In such instances, raw material costs may be lower than those encountered in Canada. The amount of capital invested may also be somewhat less. Should the soft currency countries continue to encounter difficulty earning dollars, this, too, may continue to militate against the development of Canadian sources of supply. Against all this are the higher payments and other carrying charges born of the inherent political instability characteristic of many of the underdeveloped countries. Labour, overall, may also cost more.

Several European countries suffer no such disability. Norway, like Canada, can still boast of a large reserve of untapped hydro-electric energy. Hence, along with some further additions to capacity in Switzerland, it may be called upon to meet a goodly portion of the deficit in primary aluminum which might otherwise develop in France, the Low Countries, Italy and, especially, in Western Germany.

From what has been said, it would appear unlikely that Canadian production could do better than maintain its present 20% relationship to world consumption. Indeed, it may fall somewhat over time. Meanwhile, 15% would appear to be much too low, at least through the 1960's. Quite arbitrarily, Canadian participation has been put at 17% in 1965 and at approximately 15% in 1980. Converted into absolute terms, this still makes impressive reading. Exports—depending upon whether a higher or lower forecast of world demand is used—would, under these circumstances, have approximately doubled over the next decade and multiplied between 3.5 and 4 times during the next quarter century.

Canadian consumption will, at the same time, be mounting. A forecast, detailed by the Aluminum Co. of Canada in their brief to the Royal Commission and tabled early in 1956, suggests that Canadian requirements may grow by nearly 8% per annum through to 1965 and at about 7% late in the 1980's. Since the major assumptions made in this connection are approximately in line with those used elsewhere in the Commission's staff studies and since the projected rates appear to be conservative in relation both to past domestic consumption trends and per capita requirements relative to those projected for other countries, they have been adopted, directly, in this report.

These several expectations as to Canadian production, exports, and domestic consumption are itemized in Table 21.

Table 21

CANADIAN PRIMARY ALUMINUM SUPPLIES, 1955, 1965 AND 1980

	Canadian production		Exports		Domestic consumption[a]	
	$ million	Thousand tons	$ million	Thousand tons	$ million	Thousand tons
1955....	227	584	198	507	29	77
1965....	480[d]	1200[b]	408[d]	1020[c]	72[d]	180[c]
1980....	960[d]	2400[b]	740[d]	1850[c]	220[d]	550[c]

a Per capita usage in Canada, according to these and other estimates, would be approximately 11 lb. in 1955; 18 lb. in 1955; and 40 lb. in 1980.

b Canadian production taken at 17% of world output in 1965 and 14% in 1980. World production taken as 7 million tons in 1965 and 16 million tons in 1980.

c Canadian consumption assumed to follow aluminum-iron relationship described earlier.

d Average prices of 1955 were 20.1¢ a pound. 1965 and 1980 real prices were rounded off to 20.0¢ a pound.

Any development along these lines is contingent upon imports. Bauxite or its semi-processed equivalent, alumina, will have to be brought in from elsewhere. The latter alternative may be favoured. For one thing, the shipping weight may be approximately cut in half. Political considerations may meanwhile dictate some degree of processing in the Caribbean and other tropical areas in which the raw material originates. Thus, while the "value added" in Canada may thereby be reduced, some such practice as this may serve to protect more adequately the exceptionally heavy investments in power and ingot producing facilities which will be springing up in this country.

Anchored to the forecast of Canadian production outlined previously and assuming that future increases in imports will consist largely of alumina rather than bauxite, it would appear that this country's imports of aluminum producing materials may approach $130 million by 1980.

Table 22

ESTIMATED IMPORTS OF BAUXITE AND ALUMINA, CANADA, 1955, 1965 AND 1980

Year	Bauxite		Alumina		Total	
	$ million	Thousands of tons	$ million	Thousands of tons	$ million	Thousands of tons
1955....	21	2,892	4	208	25	3,092
1965....	25	3,500	27	1,300	52	4,800
1980....	29	4,000	42	2,000	71	6,000

No discussion of the nation's trade in aluminum and aluminum producing materials would be complete without some reference being made to regional sales prospects. The relative size of export shipments to individual markets has varied, sometimes with the United Kingdom being the largest single purchaser; sometimes the United States. Sizable markets, meanwhile,

have been re-established or developed elsewhere in Western Europe and Latin America.

Industry prepared forecasts indicate expectations for the mid- and longer-term future. (See Table 23.) They show overseas shipments, particularly to the United Kingdom continuing to run ahead of United States sales over the next quarter century. Domestic requirements, while gaining relatively, may, even in 1980, account for less than one out of every four tons of aluminum ingot manufactured in this country.

Table 23

CANADIAN SHIPMENTS OF PRIMARY ALUMINUM BY DESTINATION, 1950-80

(thousands of short tons)

Market	1950	1955	1965	1980
United Kingdom	146	255	450	800
U.S.	162	194	400	750
Canada	66	77	180	550
All others	42	58	170	300
Totals	416	584	1,200	2,400

(i) *Structure of the Industry*

It was a ready supply of cheap hydro-electric power which first brought the aluminum industry to the St. Maurice Valley of Quebec in 1900. Production at Shawinigan Falls, beginning in 1901, was small by today's standards. Starting out at around 15,000 tons a year, this plant operated for many years though it has since been converted to the production of aluminum wire and cable. A second reduction plant built a few miles away still continues to produce some 60,000 tons of new metal each year. In the mid-1920's, it became apparent that in order to secure adequate low-cost power resources for its own use, the industry would have to expand elsewhere. Investigation of the Saguenay River system, which began at that time, later bore fruit in the great power plants and smelters around which the town of Arvida has since been built up.

At that, Canadian ingot capacity was only about 83,000 tons in 1939, this being about three-quarters of the total for the British Commonwealth. War production necessitated a considerable expansion.[55] New works at Arvida and Isle Maligne on the Saguenay, together with other resources in Quebec province, were harnessed to effect a fivefold increase in output by 1943. As part of this programme, a plant with an annual capacity of around 30,000 tons was built at Beauharnois near Montreal. Another at La Tuque,

[55]Some of the refinery development at Arvida (and after 1950 at Kitimat) was financed on the basis of loans and committed production by or destined for the United Kingdom. About $125 million was raised in this way.

north of Shawinigan Falls, also was operated during World War II but was shut down in 1945. The Beauharnois plant has been used since 1950, water and power conditions permitting.

Since the outbreak of the Korean war, the Aluminum Company of Canada, which has been responsible for all of these operations, undertook to expand further its primary metal capacity in Quebec. New power plants were built on the upper reaches of the Saguenay. At Isle Maligne an 85,000 ton reduction unit, commenced in 1943, was enlarged in 1950 and again in 1956. Further expansion now under way in this area is contingent on the development of an additional 750,000 kilowatts of hydro power in the Lake St. John area.

In 1950 the company also decided to start operations in western Canada. Four years later the first stage of the Kitimat project was completed, and the second commenced. Subsequent revisions in plans now call for an annual output of some 300,000 tons on the west coast of British Columbia by 1960. Ultimate capacity of Kitimat is given as 550,000 tons of aluminum ingot annually.

The corporate history of the Aluminum Company of Canada also makes interesting reading. Until 1928, a wholly-owned subsidiary of the Aluminum Company of America, it later became independent from its United States parent. At the time of the formal split with ALCOA, Aluminium Limited was incorporated as a Canadian company to carry on all of the international business formerly dominated by the Aluminum Company of America.

Aluminium Limited is a holding company with over 50 subsidiaries and affiliates operating plants in 20 different countries. These, together, constitute an integrated enterprise engaged in the production and sale of aluminum ingots and semi-fabricated products. The development of hydro-electric power incidental to this extensive undertaking also falls under this holding company's control.

The Aluminum Company of Canada Limited, together with its own subsidiaries, represents approximately 80% of the consolidated gross fixed assets of Aluminium Limited. Through its subsidiaries, ALCAN owns and operates bauxite mines, bauxite processing plants and docks, terminal and railway facilities in British Guiana; bauxite storage and trans-shipment facilities in Trinidad; fluorspar mines, and shipping, storage, terminal and railway installations in Canada.[56]

[56]Aluminium Limited reports in *Aluminium Panorama,* Montreal, 1953, that only 40% of its employees are in Canada while 85% of its fixed assets are located here. Conversely the U.K. with only 3.6% of assets, employs 18% of the company's labour force. This indicates the low ratio of labour to power and refining investment, in contrast to mining and fabricating in other countries.

The company's smelting operations are now carried on at Arvida, Isle Maligne, Shawinigan Falls and Beauharnois, all in Quebec, and at Kitimat. Fabricating operations are also conducted at Shawinigan Falls and Arvida, and at Kingston and Etobicoke in Ontario. The Aluminum Company of Canada's fabricating capacity is approximately 13% of its ingot producing capacity.

The preponderate ownership and control of Aluminium Limited still rests in the United States. As of December 31, 1955, Canadians held about 26% of the shares of Aluminium Limited. United States citizens held 72% and shareholders in the United Kingdom and elsewhere held approximately 2%. Mention should, however, be made of the fact that at the time of Aluminium Limited's formation in 1928 Canadians had virtually no equity interest in this company.

In October, 1955, a second company announced that it intended to begin operations in Canada. The Canadian British Aluminum Company is now building a plant with a capacity of 160,000 tons at Baie Comeau, Quebec. The first production is scheduled for 1957 when, it is estimated, one of the 40,000 ton pot lines will have been completed. Additional units are scheduled to begin operations in 1959, 1960 and 1965.

With the completion of these facilities and the rounding out of the full potential of the Kitimat project in British Columbia, Canada will have a primary aluminum producing capacity of over 1.4 million short tons. (See Table 24.)

Table 24

CURRENTLY PLANNED CAPACITY, CANADA, 1955-65

(quantity in thousands of short tons)

	1955	1956	1957	1958	1959	1960	1965
Aluminum Co. of Canada Ltd.							
Quebec							
Arvida	362	362	362	362	362	362	362
Isle Maligne	93	115	115	115	115	115	115
Shawinigan Falls	68	68	68	68	68	68	68
Beauharnois	37	37	37	37	37	37	37
Other	—	—	—	—	25	120	120
British Columbia							
Kitimat	90	180	180	260	300	300	550 (est.)
Canadian British Aluminium Co.							
Quebec							
Baie Comeau	—	—	40	40	80	80	160
Total	650	762	802	882	987	1,082	1,412

Set in perspective against developments which have been planned or projected elsewhere, this construction of new capacity gives added substance to the preceding forecast of Canadian output which shows Canada falling only modestly behind the steady upward trend in world production over the next decade. (See Table 25.)

Table 25

PROJECTED PRIMARY CAPACITY (excl. U.S.S.R.), 1955-60

(thousands of short tons)

	Production 1955	Capacity 1960	Percentage increase 1955-60
Canada	584,000	1,082,000	80
United States	1,566,000	2,420,000	54
Free Europe	600,000	880,000	46
Africa	—	50,000	—
Latin America	3,000	35,000	1,070
Free Asia and Pacific	80,000	160,000	100
Total	2,857,000	4,627,000	63

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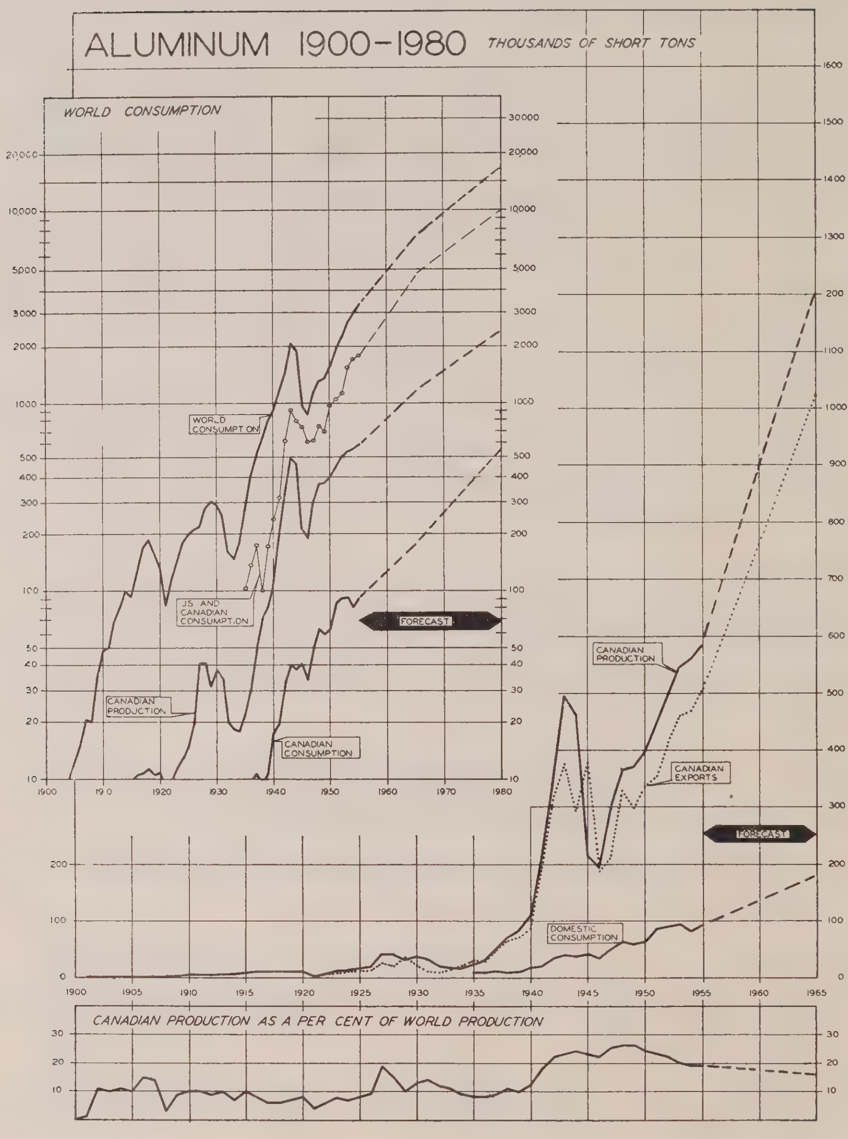
ALUMINUM 1900-1980
THOUSANDS OF SHORT TONS
WORLD CONSUMPTION
WORLD CONSUMPTION
US AND CANADIAN CONSUMPTION
CANADIAN PRODUCTION
CANADIAN CONSUMPTION
FORECAST
CANADIAN PRODUCTION
CANADIAN EXPORTS
FORECAST
DOMESTIC CONSUMPTION
CANADIAN PRODUCTION AS A PER CENT OF WORLD PRODUCTION

H. Magnesium

As in the case of aluminum, there are many factors which favour the production[57] and export of magnesium metal from Canada. Both are drawn to sites where cheap power can be supplied in comparatively large quantities; both are readily marketed in ingot form; both are commodities whose world demand is growing much faster than for any other common metal.

Not only is magnesium one of the earth's most abundant elements, but the problems associated with its extraction have now been largely overcome. As a result its cost of production has been declining, a trend which will doubtless continue relative to other materials as its volume of output increases. For the first time, plants suitable for its fabrication are now enabling magnesium to enter into competition with other metals on a large tonnage basis. These developments together with the emergence of a variety of applications, some of which are predicated upon an element with magnesium's particular chemical and physical properties, are among the reasons why the primary processing of this metal could well become a sizable industry in this country. As is the case with other commodities, markets of substantial volume and continuity of access must be available. Indeed, with magnesium, as with many another new product, this has been the crux of the problem. Variable defence demands, lack of domestic fabricating facilities, protective tariffs elsewhere, and the comparative slowness with which potential users have designed this new metal into their products will be blamed for much of the uncertainty which has surrounded the outlook for this commodity. Greater market stability, together with the emergence of a sizable civilian market has, however, improved the prospects for this industry since 1950. During the period of 1950-55 world production rose by 200%; the Canadian and United States productions, by over 300%.

Though its production had commenced much earlier, World War II provided the impetus necessary to get magnesium metal output under way on a large scale.[58] In the United States alone, 15 plants were built, 13 employing government funds. In this country, the Canadian-developed Pidgeon process was put to use. Once proven, it was also adopted in the United States.[59] Elsewhere, particularly in Germany and the United King-

[57]Canada produced some 9,000 tons of the metal in 1955, valued at approximately $5.8 million. Of this, over 80% was exported. Canada is, at present, the world's largest exporter of magnesium and produces commercially, without any additional refining, the highest purity magnesium on the world's market.

[58]Germany was the sole producer of magnesium until World War I, when production started elsewhere. In Canada, it was first produced by Shawinigan Electro-Metals Co. Ltd., in 1915, from materials imported from the U.S. This plant operated until 1919, when it was closed down. After 1920 the North American production of magnesium was negligible; European technology and consumption was well ahead. Germany remained the world's principal producer until 1942.

[59]Known technically as the silico-thermic or ferro-silicon process, it was employed in six plants built in the U.S. during World War II, all of which were closed down in 1945. Production in four of these government-owned plants was revived in 1950 for the Korean war. At present, one plant in Canaan, Connecticut — capacity 5,000 tons per annum — is still in operation for the atomic energy defence programme. The remainder, being relatively high-cost plants, were again shut down. Of the two main processes for the production of magnesium, electrolysis of magnesium chloride accounts for over 90% of the total output. Though there are various thermal processes for the reduction of magnesium ores, the only one in commercial operation at the present time is that involving the reduction of magnesium oxide by ferro-silicon.

dom, manufacture of the metal was also accelerated. So much so that world output rose more than tenfold in the years between 1939 and 1943.[60] User industries, meanwhile, learned to overcome such hazards as the high inflammability of magnesium cuttings and dust and, at the same time, to employ it and its alloys more advantageously, particularly in the production of aircraft.

Consumption on this continent, which was approaching 160,000 tons annually in the peak year of 1943, fell drastically with the cessation of hostilities. Cancellation of defence contracts, together with a substantial recovery of magnesium from aircraft scrap, caused new metal requirements to fall to less than 10,000 tons in 1947.[61] Revival was slow. Commercial applications of comparable volume were not readily forthcoming. Edging up slowly at first, and then hastened by the defence requirements stemming from the Korean war, the market has since called some of the redundant World War II capacity back into play. Output from private facilities has, at the same time, been expanded.[62] North American consumption, including United States government purchases for stockpile, is presently about 70,000 tons annually, but even more reassuring is the fact that civilian requirements are larger and growing much more rapidly than was the case in the immediate postwar period.[63]

Mention has already been made of some of the deterrents to greater use, particularly in commercial applications. Most difficult to overcome were the prejudices of inflammability and corrodibility. The belief that magnesium "burns" came from its early use in pyrotechnics and incendiary bombs. In fact, the high thermal conductivity of magnesium prevents it from burning unless it is first melted by an otherwise disastrous fire. High corrodibility is also easily avoidable if proper care is taken in production, design and surface treatments, but problems connected with effective corrosion protection of magnesium products, when used in contact with other metals, had to be solved.

Special design methods had to be worked out to take into consideration its specific combination of properties and its limited formability at room temperature. Lack of suitable fabricating facilities has subjected magnesium to a severe price penalty. Rolled and forged on equipment formerly used for the initial manufacture of aluminum products, it has suffered both in respect to cost and quality. Now the situation is changing, at least in the

[60]From 27,000 tons in 1938 to 265,000 tons in 1943. In the U.S., production increased from about 3,000 tons in 1939 to a peak of 184,000 tons in 1943; in Canada, to over 5,000 tons a year later.

[61]Recovery of magnesium from scrap has ranged all the way from around 10% late in World War II to nearly 60% in 1947. At present it is in the order of 20%.

[62]The Dow Chemical Co. with an annual capacity of around 70,000 tons (30,000 tons in its own plant at Freeport, Texas, and 40,000 tons at the U.S. government-owned plant at Velasco, Texas, under a three-year lease agreement); and the Dominion Magnesium Limited and the Magnesium Co. of Canada Limited, with a combined capacity of around 12,500 tons, are still the only private companies producing magnesium in North America today. As announced recently, a new silico-thermic magnesium production plant, rated at 10,000 tons annual capacity, is being built by Alabama Metallurgical Corp. at Selma, Alabama. This new firm is a subsidiary of Brooks and Perkins Inc., Detroit, and Dominion Magnesium Limited, Toronto.

[63]At present, Canada and the U.S. together are capable of producing about 160,000 tons of new metal annually. Output in the two countries was in the vicinity of 78,000 tons in 1956.

more industrialized countries. With the construction of specially designed and larger scale facilities for rolling, extrusion and press-forging, as well as due to improvement or adaptation of special fabricating methods for deep-drawing, impact extrusion, spinning, die casting, etc., this particular handicap is being progressively removed. So much so, that a number of structural magnesium products have currently become competitive with aluminum in many of the latter's larger volume applications.

Recent important developments preparing the North American magnesium industry for a larger role in the metal field include the installation of the first large rolling mills and extrusion plant by Dow at Madison, Illinois; the erection of heavy forging presses by the United States Air Force; the design and construction of an entirely automatic hot-chamber die casting machine for magnesium that shows considerable savings in production costs and makes magnesium competitive with aluminum and zinc alloys; the expanding use of new magnesium alloys containing zirconium, rare earth metals, thorium, silver, beryllium, etc.; new and very effective hard coatings for increased wear and corrosion resistance of magnesium products; the development of casting methods for thin-walled (one-eighth inch and less) castings; the commercial acceptance of electroplating of magnesium products; the steady increase in magnesium components for the automotive industry; and many more.

Despite the violent defence-induced swings which have occurred in the market for this ultra light metal,[64] its long-term trend in consumption has been decidedly upward. Since the mid-1930's, it has been of the order of 12% yearly. Even if defence requirements once more level off, demand from now on may be expected to mount at a rate in the order of 10% per annum. This figure, though it is slightly higher than that chosen for aluminum, has been used in our forward projections to 1965. Thereafter an annual growth in consumption of 8% may be more appropriate both to Canadian and world export requirements. A comparison of the production curves for aluminum and magnesium reveals interesting parallels. Both show wide swings, up and down. The latter, however, follows with a time lag of about 35 years.

New uses have been developed and old ones continually expanded. Not all of them are structural in nature. A growing proportion of new magnesium output is being used as a raw material in the manufacture of other metals and as an addition to various industrial alloys. In 1955, civilian and commercial applications accounted for 55% of the total United States magnesium consumption and exceeded, for the first time in the history of this metal, military aircraft and other defence industry uses. The production figures already show, too, the impact of new fabricating facilities and techniques on magnesium product shipments in the United States (increase in castings was 9% in 1955 and 30% in 1956, in wrought products 54% in 1955 and 20% in 1956).

[64]Magnesium is about two-thirds the weight of aluminum; somewhat over one-third that of titanium, and less than one-fourth that of steel.

Among its more popular structural applications is its use in the aircraft industry, especially for landing gear; in the construction of highway transport, materials handling equipment, jigs, gauges, fixtures, portable power tools and chain saws, textile machinery, cameras, binoculars, typewriters, dictating and recording equipment, and a host of other consumer products from vacuum cleaners to snow shovels, where a reduction in weight or lowering in fabrication costs has considerable appeal. Now available in extra wide sheet form, substantial tonnages are being used in lieu of aluminum in both commercial and high speed military aircraft. Airborne equipment now incorporates magnesium castings and sheet products for many structural purposes. Magnesium sheet is used in truck bodies, tool plates, ultra light luggage, printing and engraving plates; sheet products in military electronics equipment and even in the much publicized earth satellite (Project Vanguard). Mention should be made also of the use of magnesium as a canning material for fuel element in gas-cooled nuclear energy reactors. Newly developed alloys containing thorium have exceptionally good properties at elevated temperatures (up to 350°C or 650°F) and are used in jet engines and guided missiles.

Non-structural applications of magnesium are exceeding its structural uses. The use of magnesium as an alloying element in aluminum,[65] to increase its strength and corrosion resistance, is growing. Similarly, magnesium is being added to zinc die casting alloys to improve their corrosion resistance and dimensional stability. The Kroll process in the manufacture of titanium requires magnesium in amounts exceeding the titanium metal produced.[66] In much the same way, smaller quantities are currently being sold for the reduction of several other new metals including uranium, zirconium and hafnium. Obviously, these latter demands are associated, in no small measure, with the prospects for nuclear power. Other metallurgical uses include the addition of magnesium as an inoculating agent to nodular iron and as a desulphurizing agent to steel.

The cathodic protection of corrodible metals, particularly iron and steel, is yet another non-structural use of considerable promise. The high contact potential of magnesium and its freedom from polarization effects make it an ideal material to employ as galvanic anodes to protect pipelines, buried structures, industrial boilers, water heaters, hulls and compartments of ships, and other equipment in contact with seawater, soil or other chemically active substances. Another application with considerable promise for the future is the manufacture of dry cell batteries, where magnesium might replace zinc.

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[65]About 20% of the present demand for magnesium consists of metal used in the alloying of aluminum. Because the magnesium content of these alloys is steadily rising and because the demand for aluminum itself may mount at a rate in excess of 8% a year, this alone points to a substantial strengthening in the world market for magnesium metal.

[66]i.e. approximately 1.2 pounds of magnesium per pound of titanium sponge produced. Even with recovery some 0.3 pounds are "consumed" in this process.

In terms of resources and industrial competence, Canada is well equipped to tap these new found markets. At present the world's third largest producer, behind the United States and the U.S.S.R. but exceeding the United Kingdom and Norway, Canadian plants are currently turning out some 10,000 tons of new metal annually. Dominion Magnesium Ltd. using the silicothermic process at Haley, Ontario, has an annual capacity of around 8,000 tons. The Magnesium Co. of Canada Ltd., a wholly owned subsidiary of Aluminium Limited, Montreal, makes magnesium by the electrolysis of magnesium chloride. With an ore processing plant located at Arvida and drawing its magnesium-containing ore, brucite, from its own mines near Wakefield. Quebec, it is presently capable of producing as much as 4,500 tons of metal yearly. Both companies rely on hydro-electric power as their source of energy.[67] Both are heavily engaged in the export trade, over 80% of their output being sold abroad. Wrought product fabricating facilities are seriously limited in Canada. No sheet rolling or press-forging facilities exist. Until the installation of such plants can be economically justified, the use of magnesium metal in this country will be seriously retarded.

What are the industry's growth prospects? Besides the deposits of dolomite and brucite already being worked, other sources are known to exist in both western and eastern Canada. A substantial occurrence of magnesite is known in British Columbia. Suitable natural brines exist in Saskatchewan. On both coasts, there is, of course, easy access to sea water and, in a number of situations, cheap hydro-electric power or natural gas (or both) are readily available. By contrast, energy is relatively expensive in Japan, the United Kingdom and most of Western Europe. Even in the United States natural gas cannot be expected to serve this purpose indefinitely. Therefore, given access to these markets, this Canadian industry might grow at a rate considerably in excess of the world average. It is, however, in this latter connection, that the greatest difficulties have been and may continue to be encountered.

Near-term sales in the United States, for example, must be discounted. The present tariff, amounting to more than 50% ad valorem, effectively wipes out any natural advantage which Canada might have in this quarter.[68] At least as long as excess refining capacity exists there, this situation might be expected to continue. Many another country similarly concerned with self-sufficiency and finding source materials within their borders, may attempt to produce most, if not all, of its own requirements. On the other hand, Canadian-produced magnesium, alloyed with aluminum

[67]The production of magnesium by electrolytic methods requires approximately 10 kilowatt-hours of electricity for every one pound of new metal. In this respect, it approximates aluminum in its electric power requirements. The ferro-silicon plants, on the other hand, require between four and five kilowatt-hours per pound of output. There is, of course, considerable electrical power requirement in the production of the ferro-silicon itself.

[68]The present U.S. tariff on magnesium metal and related products is as follows: 17¢/pound for magnesium metal; and 19¢/pound on magnesium content plus 9.5% ad valorem for alloys, sheet, tubing, wire, powder, etc.

prior to exportation, might hurdle some of these barriers[69]. As Western Europe grows industrially, export markets for the metal might be found in addition to those which might be expanded in the United Kingdom and Japan. It is with these considerations in mind that the following forecast of Canadian production, exports, and domestic consumption of magnesium metal have been prepared.[70]

Table 26

MAGNESIUM — PRODUCTION, EXPORTS AND CONSUMPTION, 1955, 1965 AND 1980

Year	Production		Exports		Consumption	
	Tons	$ million	Tons	$ million	Tons	$ million
1955..........	9,000	5.8	7,500	4.8	1,500	1.0
1965..........	20,000	11.6	16,000	9.3	4,000	2.3
1980..........	50,000	24.0	38,000	18.2	12,000	5.8

In the foregoing, it is apparent that Canadian output is and will continue to be largely contingent on the industry's export expectations. In this connection, it has been assumed that world requirements will somewhat more than double over the next decade, reaching something like 300,000 tons in 1965. Thereafter, with requirements more dependent upon developments in civilian applications, a somewhat slower rate of growth might see this ranging around 750,000 tons annually 25 years hence.

Should Canada roughly hold its own, output in this country would consequently be around 20,000 tons in 1965 and in the vicinity of 50,000 tons in 1980. A lack of adequate fabricating facilities may limit local requirements over the next decade. Thereafter, an acceleration in domestic consumption may compensate for a proportionate falling-off in this country's contribution to the international trade in magnesium metal which may develop during the late 1960's and 1970's. Should it, at the same time, prove possible to export substantial tonnages of aluminum alloys with a sizable magnesium content, foreign sales might effectively be higher than the amount suggested in the above table.

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[69]Canada exports practically all of its aluminum in primary form. Should alloying with magnesium take place here, the demand for virgin metal would increase substantially.

[70]It has been assumed, when forecasting dollar value, that the price of magnesium relative to other goods and services will decline by approximately 10% between 1955 and 1965 and by 25% over the 25-year period ending in 1980.

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I. Titanium

In company with aluminum and magnesium, titanium is frequently referred to as a light metal. Even more recent in industrial application, its present status may be compared to that of aluminum immediately prior to World War I or to magnesium as the latter emerged from World War II.

New capacity, built primarily for defence purposes, is now producing significant quantities of metal, some of which is finding its way into commercial channels. Yet the very properties which recommend titanium to designers are frequently obstructed by other and equally practical considerations. The necessity of using highly specialized production techniques, its relatively high unit cost, and the time and experimentation required for its introduction on a truly commercial scale are all obstacles which must be overcome before titanium gains a place among the larger tonnage metals entering into Canada's domestic and international trade.

Variously described, it has sometimes been referred to as a wonder metal. The aircraft industry, in particular, has high hopes for its use. Others, more concerned with the immediate problems of sponge production, melting and fabrication, have dubbed it "that vexatious metal". The optimists still regard it as potentially the middleweight champion of the metals, standing midway between aluminum and steel. Meanwhile, the skeptics, and there are quite a few of them, are inclined to relegate titanium to the position of a comparatively minor element in the structural materials field.

This controversy is of more than passing interest to Canadians.[71] This country possesses one of the world's largest single known reserves of ilmenite, a major titanium bearing ore. It has, since 1951, become one of the world's largest producers of titanium concentrates.[72] Canada, as is well known, has

[71]Canadian production of titanium ores and concentrates in 1956 was valued at $6 million. Imports of titanium dioxide, in the same year, amounted to more than $12.6 million. The corporate structure of this industry is interesting. The great bulk of Canadian mine and titanium concentrate production is owned and controlled by the Quebec Iron and Titanium Corporation Ltd. This is a wholly owned subsidiary of two large United States mining corporations, the Kennecott Copper Corporation (two-thirds) and New Jersey Zinc Company (one-third). Canadian Titanium Pigments Ltd., now erecting an oxide manufacturing plant at Varennes, Quebec, is a wholly owned subsidiary of the National Lead Co. (U.S.). Several companies have indicated an interest in producing sponge in this country, provided that they can obtain the necessary government contracts. One is Electro Metallurgical Co. of Canada Ltd., located at Welland, Ontario, a wholly owned subsidiary of Union Carbide and Carbon (U.S.). Another is Canadian Industries Ltd., a subsidiary of Imperial Chemical Industries Ltd. (United Kingdom).

Canadian companies which have been conducting pilot plant studies in this field are the Shawinigan Water and Power Co. Ltd. of Montreal and Dominion Magnesium Ltd., whose major metallurgical works are at Haley, Ontario.

[72]The Allard Lake deposits in Canada include an indicated reserve of 150 million tons running 35% titanium oxide and 40% iron. The first large-scale shipments of ore from the mine at Allard Lake was made in 1950. Smelting began at Sorel, near Montreal, in the following year. Production figures for the period of 1950-56 are listed in Table 30.

an abundance of low-cost water power. It also possesses many of the secondary and other industries necessary to serve one or more refineries. Two things, however, are lacking. One is process know-how; the other, markets. Both are serious short-comings and must be overcome if titanium metal is to be produced economically in this country.

Reference has already been made to some of the problems associated with the manufacture and marketing of titanium metal. Its price, though steadily declining, is still many times that of most other metals with which it must eventually compete.[73] There were many attempts at developing a new and cheaper method of titanium production, but none so far has proven itself better than the Kroll process, the principal one now used commercially. Plants which have so far been built are still too small to reap the full economies of scale. Processing at all levels must be carried out under specially controlled conditions. New techniques, using high-vacuum or inert-atmospheres and calling for more equipment and control than has commonly been the case with other metals, have had to be adopted. Wastage is also a problem. Much of the scrap, having absorbed nitrogen, oxygen, carbon, or hydrogen, cannot be re-worked simply by blending. This, too, adds to costs. Thus it might be a number of years before titanium, in sufficient tonnage and in a wide variety of shapes, may be available at prices which bear comparison with those, say, of aluminum and stainless steel.

From the Canadian point of view, there are other and equally serious limitations. Though it has its possibilities, ilmenite has yet to replace rutile which is at present the more satisfactory source material for metal production. Besides, ores more amenable to beneficiation than those in Quebec occur in a number of other places. Production of ilmenite concentrates in the United States, for example, is more than five times the Canadian total.[74] Other deposits of ilmenite and titaniferous iron ores are known to occur in India, Norway, Japan, Egypt, Africa, Ceylon, Malaya, Sweden, Brazil, Mexico and the U.S.S.R. Rutile and ilmenite, along with other minerals, are found in beach sands in many places. These include the Atlantic and Gulf coasts of North America. Ilmenite is also present in Arkansas bauxite and Florida phosphate. Therefore, unlike copper and lead, a scarcity of ore will not limit the importance of titanium, nor, for that matter, add appreciably to the cost of mining it.[75]

Concentrating by smelting, and this means largely the elimination of iron, has presented its own set of problems. However, at least one process

[73]Titanium metal in sponge form is presently being marketed at about $2.50 to $2.75 a pound. Aluminum ingot, by contrast, is available at 25¢ a pound. Stainless steel ingot, depending upon its quality, can be bought for prices ranging anywhere from 50¢ to 60¢ a pound.

Cost of fabricating titanium is exceptionally high. Using mills which have been developed essentially for other purposes, titanium and its alloys may tie up capital for between ten and twenty times as long as, say, copper or brass. This points first to the development and later to the utilization of all titanium mills.

[74]One mine, at Tahawus, N.Y., (operated by National Lead Co.) led all others in 1955. In that year, it produced approximately one-half of the total United States output. One-third came from the beach sands deposits in Florida; the remainder from mines in Virginia, Idaho and South Carolina.

[75]World production of ilmenite concentrates is presently in the order of one million tons. Chief producer is the United States, followed by India, Norway, Canada and Malaya in that order. World production of rutile concentrates is currently in the order of 60,000 tons. By far the largest producer is Australia, the second largest the United States; Mexico is also potentially a large producer.

capable of separating a titanium-rich slag from ilmenite ore has been evolved. Partly because smelting at this stage involves the use of electric power, this operation has been sited in Canada. The disposal, locally, of by-product iron has also facilitated, to some extent, this development. Most of the iron, however, has been shipped as far afield as Western Europe.

When it comes to producing either refined titanium dioxide or the metal itself, still heavier capital outlays are involved. Furthermore, much experimentation, some of it on a full plant scale, remains to be done. This is why the cost of raw materials (i.e. titanium slag and electric power) is still quite small relative to the price of titanium sponge. There are powerful influences which dictate the location of refineries. One is the United States tariff.[76] At 20% ad valorem, it rules out the possibility of Canadian exports to the United States. Another is government support. In the United States and, to a lesser extent, in Japan and the United Kingdom, new projects are being underwritten by government loans, long-term defence contracts, fast tax write-offs and assistance in the form of government sponsored research.[77]

Finally, there is the question of scale. To be truly economic, much larger plants than those at present under construction must be built. Expert opinion in the industry[78] holds that, to be reasonably efficient, future refineries must be in the 20,000 to 40,000 ton a year category. Only when they reach this size are they likely to be able to produce titanium sponge profitably at a price as low as $1.15 a pound (i.e. a price at which titanium metal will begin to be of interest to a substantial number of commercial users).[79]

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[76]Because the U.S. tariff is a limiting factor, some further description might be useful. Titanium in ores, concentrates (and this includes basic titanium slag ground or unground) are on the free list. These are all materials which are "not advanced in value or condition". Titanium dioxide, suitable for making pigments is subject to a U.S. tariff of 15%. Titanium metal in either sponge or ingot form is required to pay 20% ad valorem. Ferro-titanium has a tariff of 12.5% ad valorem. Depending upon the other constituents, titanium alloys must pay a tariff of from 12.5% to 25% ad valorem.

Canada also imposes certain duties on titanium and its compounds. Imports of pigment under British Preference pay no duty. Originating in the U.S. or other countries, they are subject to a tariff of 12.5%. Titanium metal powder or sponge enters free under British Preference but faces a 15% to 25% ad valorem tariff if from the U.S. or other countries. Mill products all face a tariff of from 15% to 25%.

[77]Because of the nature of this new strategic metal industry—that is: (1) high plant cost; (2) high operating cost; (3) limited civilian applications; (4) purchases in time of excess supply for a temporary government working inventory; (5) loans for pilot plants; (6) demonstration to contractors of all steps in production at the U.S. Bureau of Mines pilot plant at Boulder City, Nevada.

[78]See H. H. Kellogg, "What the Future Holds for Titanium", *Engineering and Mining Journal*, Vol. 156, April, 1955.

[79]There is a tremendous spread between the price of titanium in its crude ore form and in semi-fabricated products such as sheet, rod, and bar. Whereas the former may be obtained for a few cents a pound, the latter cost $7 a pound and upward.

The following table, giving a breakdown of current and possible future price relationships, gives some indication of the value added by processing.

Titanium Prices, February, 1957

	Current price(a) $/lb.	Price at maturity(b) $/lb.
Crude ore	0.003	—
Slag (70% TiO_2)	0.020	—
Slag (80% TiO_2)	—	0.02
Sponge (Grade A)	2.50-2.75	1.15
Forging billet	6.85-7.10	1.78
Plates	9.25-11.25	2.06
Sheets (less extras)	11.40-12.10	2.34
Bars and rods	7.10-7.35	—
Wire	8.50-9.00	—

(a) As quoted by *American Metal Market*, February 15, 1957 (ex. crude ore).
(b) Predicted by H. H. Kellogg.

One or more of these appropriately scaled plants may eventually be located in Canada. With sponge selling at a price below $2 a pound and raw materials and power, together, constituting 25% to 30% of total costs, a greater degree of resource orientation would have its advantages. Overseas users, lacking cheap energy, might then find it preferable to buy metal from this side of the Atlantic. Yet, a review of current developments makes it appear doubtful that this sort of thing will begin to happen much before 1965. Indeed, it might be 1970 or later before requirements outside the United States will rise to the point where a sizable Canadian contribution of sponge metal is called for.

A good deal of new capacity is under construction. In the United Kingdom, Imperial Chemical Industries Ltd. has completed a plant expansion of 1,500 long tons annually. Part of their projected output is covered by government contract. Japan began to produce titanium metal in 1952. Four companies produced about 1,500 tons in 1955. A goal of about 2,000 tons has been set for the fiscal year 1956. Although most of the Japanese production is exported to the United States, some has been sold in Western Europe.

In the United States, an even more ambitious programme is under way. Production, which amounted to only about 500 tons in 1951, exceeded 14,000 tons in 1956, an almost thirtyfold increase. A great deal more capacity is under construction. Half a dozen plants, one or two of them capable of producing as much as 7,500 tons of sponge a year will come into operation during the next two or three years. Thirty-five thousand tons a year of capacity is the official target for 1960.[80]

It will be some time before aircraft and naval applications, as well as the use of titanium metal in the food processing, chemical and chemical process industries will reach a volume commensurate with the primary industry's new found ability to produce sponge.

Eventually, much if not all, of this defence financed capacity will be put to work. A ready supply of metal, itself, will stimulate greater use. Process improvements will be followed by further price cuts. And gradually the logic of producing titanium in places like Quebec will become apparent.

Unfortunately the Canadian market, alone, will be too small. Ten years from now it will still be limited to the production of military aircraft, a few naval vessels and whatever small commercial market has developed by that time.[81] So it is to markets in the United Kingdom and, possibly, con-

[80] In the U.S., production is expected to run somewhat at follows: 1956, 14,500 tons; 1957, 22,000 tons; 1958, 25,000 tons.

[81] The future military aircraft market for titanium metal will be influenced by two trends, each counteracting the other. The technology of titanium alloy production and fabrication has now reached the point where aeronautical engineers can confidently design air-frame and engine components using titanium alloys. The production capacity is also sufficient to assure an adequate supply of material. This condition should lead to a rapidly expanding market for titanium alloys in this field of application.

The replacement of many manned military aircraft by guided missiles is thought to be inevitable. These missiles are being designed to fly at extremely high speeds where aerodynamic heating (the so-called thermal barrier) could rule out titanium. Stainless steel would have to be used. This could cause a reduction in the amount of titanium metal required for military aeronautical applications after 1965.

There will be other markets for titanium metal. If the demand for nickel alloys such as stainless steel in industrial corrosion resistant applications keeps growing, it may outstrip supply. Meanwhile the price of titanium alloy mill products will be falling. It is therefore possible that this market for titanium metal could become quite important over the next two or three decades.

tinental Europe that this country will have to turn in order to launch a truly viable titanium reduction industry.

That this country will become a favoured source of supply, even in the late 1960's, is open to question. Norway, like Canada, has cheap hydro-electric power. It has its own large reserves of titaniferous iron ores. Until developed in the main user countries, the process know-how and much of the necessary plant will be imported. Produced outside the dollar area, Norwegian metal would be purchasable with sterling. Neither can possibilities in one or two other countries be ignored. For these several reasons, any forecast of Canadian titanium metal production for export must be regarded as tentative in the extreme. This table is included to show what might happen rather than what will happen.

Table 27

ESTIMATED PRODUCTION, EXPORTS AND CONSUMPTION OF TITANIUM METAL IN CANADA, 1955, 1965 AND 1980

	Volume in thousands of tons			Value $ million		
	1955	1965	1980	1955	1965	1980
Production	nil	10	25	nil	30	75
Exports	nil	5	15	nil	15	45
Consumption	—	5	10	—	15	30

The market and technological problems associated with production of titanium metal are such that it may be many years, if not decades, before the quantity of ore used in this way is commensurate with that being employed for other purposes. Even today, with a great deal of emphasis being placed on defence requirements, less than 10% of all the titanium ore mined throughout the world is being devoted to metallurgical purposes. As late as 1955, over 95% was still going into the manufacture of paint, ceramics, linoleum, paper, rubber, and chemical products. Furthermore, it has been largely to service these latter demands that the North American mines have been opened up. Hence, it is only through a consideration of the demands originating in the non-metals sector that we can obtain a realistic appraisal of the near-term prospects for titanium mines production and exports from this country.

Mined as a crude ore at Allard Lake, Quebec and relieved of much of its iron and gangue content by beneficiation and smelting at Sorel, virtually all of this material is being sold in slag or concentrate form to a number of large paint manufacturers in the United States.[82] In 1955, this production (all of it for export) was about 163,000 tons of slag. In terms of oxide, this is equivalent to approximately one-half of all North American requirements.

[82]These include the Glidden Co., American Cyanamid, E. I. Dupont de Nemours and the New Jersey Zinc Corp. It will soon include the National Lead Co. which operates the world's largest single mine in New York State and is at present constructing a titanium dioxide plant in Canada for supplying the domestic market. This pigment plant has a contract for the supply of titanium raw material from Sorel.

One of the factors which will influence future prospects is the rise in demand for titanium dioxide. Since the end of World War II, it has grown rapidly, largely displacing zinc oxide in the manufacture of white pigments. This process of substitution is, however, coming to an end. Already, 80% of the white pigment market has been taken over in the United States; 75% in Canada. Zinc also is likely to be more difficult to displace in its remaining applications. Thus, it is to the over-all rate of growth in demand for white pigments that we must turn in order to obtain some indication of what the future may hold.

Because it provides by far the largest market (75% in the United States and 85% in Canada), the growth of the paint industry would, at first glance, seem to be the most relevant. Its long-run annual compound rate of growth has been in the order of 5%. Yet, as it turns out, this figure cannot be used directly. It would appear to be far too optimistic when applied to prospective sales of white pigments. These have been expanding at only about one-half the rate recorded by paints in general. Other colours are gaining a much greater degree of consumer acceptance. A growth rate of about 2.5% annually has, therefore, been taken as indicative of the future demand for titanium oxide in paints. Other uses, though more modest, are slowly developing in the chemicals, rubber, paper, furnishings, and building materials industries. In order to allow for this further diversification, the over-all North American demand for titanium oxide has been assumed to rise at a 3% per annum rate more or less indefinitely, into the future.

A measure of over-all market growth is one thing; the share that falls to Canadian industry something else again. Any forecast of this kind is also rendered hazardous by the widespread occurrence of titanium ores (mentioned previously) and the developmental problems which still remain to be overcome in respect to the elimination of iron and other by-products or waste materials which they contain. Quite arbitrarily, it was, therefore, assumed that Canadian production will continue to supply the same proportion of total North American demand as was the case in 1955. A fall in price relative to other goods and services was anticipated.[83] Thus Canadian production and exports of concentrates in terms of titanium dioxide content, could appear as shown in Table 28 in 1965 and 1980.

Table 28

ESTIMATES OF PRODUCTION, EXPORTS AND DOMESTIC CONSUMPTION OF TITANIUM CONCENTRATES, CANADA, 1955, 1965 AND 1980

	Production		Exports		Domestic consumption	
	Tons	$ millions	Tons	$ millions	Tons	$ millions
1955	117,042	5.2	110,000	5.1	nil	nil
1965	300,000	13.4	270,000	12.5	30,000	1.4
1980	600,000	24.0	540,000	21.6	60,000	2.4

[83]Down 10% by 1965 and 25% by 1980.

Table 29

ESTIMATES OF PRODUCTION, IMPORTS AND DOMESTIC CONSUMPTION OF TITANIUM DIOXIDE, CANADA, 1955, 1965 AND 1980

(value in $ millions of titanium dioxide)

Year	Production	Imports	Domestic supply
1955	—	10.5	10.5
1965	12.7	—	12.7
1980	17.6	—	17.6

Table 30

CANADIAN TITANIUM ORES AND CONCENTRATE PRODUCTION

(short tons)

Year	Crude ilmenite	TiO^2 concentrate (slag)	TiO^2 content Tons	TiO^2 content $000
1950	101,970	2 248	1,596	150
1951	373,786	19,643	14,123	739
1952	266,461	42,141	30,805	1,238
1953	129,965	140,992	100,527	4,206
1954	304,550	122,960	88,408	3,841
1955	445,635	162,784	117,042	5,193
1956	560,362	195,156	134,500	6,000

Table 31

CANADIAN IMPORTS OF TITANIUM DIOXIDE, BY COUNTRY

(including pigments containing not less than 14%Ti)

Year	From U.S. Short tons	From U.S. $000	From U.K. Short tons	From U.K. $000
1949	20,075	4,903	718	255
1950	23,987	6,118	3,138	936
1951	26 052	6,839	3,596	1,624
1952	21,469	5,266	2,736	1,091
1953	23,970	5,647	7,930	2,820
1954	22,714	5,748	9,392	3,381
1955	25,315	6,536	10,484	3,969
1956	27,535	8,638	9,715	3,884

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J. Gold

The gold industry is confronted with a set of circumstances unprecedented in the history of Canadian mining. Canada-United States dollar exchange rate fluctuations excepted, the price to Canada's gold producers has remained unchanged for more than 20 years. Costs, meanwhile, have been rising. Since the mid-1930's, they have increased by something like 50%.[84] Caught in this squeeze between a ceiling on income and steadily mounting expenses, profits, new investment, production and employment in Canada's gold mining industry are being forced steadily downward. Should these influences continue to be at work over the period under review, gold mining—which ranked first among all of Canada's metal mining industries as late as 1940—may well have fallen to fifth or sixth place by 1980.

Canada's gold mines and producers are not alone in their plight. Similar conditions exist elsewhere. Costs are rising. In the United States, gold production, whether it be placer or straight lode mining, is without benefit or subsidy. Hence the marginal mines are without the type of assistance as is provided by the federal government in Canada.[85] On the other hand, mines

[84]By effecting a 50% increase in output per wage earner per year, they have (when a decline in hours worked per week is also taken into account) managed to show a long-run productivity gain in the vicinity of 2% per year. Since the tenor of the ore and the conditions under which new metal is being produced have, at the same time, been deteriorating, this is a remarkable performance. See *The Report of the Committee of Inquiry into the Economics of the Gold Mining Industry, 1955.*

[85]Some two-thirds of gold production in the U.S. is still produced by other than by-product base metal mines. About 22% comes from placer mines and 40% from precious metal ores.

in the sterling area benefited from the devaluation of the British pound in 1949. Special tax concessions are granted to gold mines in Australia. And, in numerous other countries, partial relief has also been afforded by subsidies, tax concessions, and the sale of some part of current production at premium prices on the free market.[86]

The central problem of the gold mines—that of increasing productivity and hence reducing costs at a rate sufficient to offset the effect of inflation—though difficult, have not yet proven to be insurmountable. World output, for one thing, is continuing to edge upward. New gold districts, particularly in the Orange Free State and the Transvaal in the Union of South Africa are being added to older fields.[87] Many of the largest straight gold producers are still operating at a profit and paying substantial dividends.[88] Even in Canada, where there are alternative opportunities for employment and investment adding to the industry's difficulties, a number of the more substantial producers can be expected to remain in operation for many years. This they can do, without any government assistance whatever. The output of gold generated as a by-product of copper and other non-ferrous metals mines; meanwhile, is rising. These are among the reasons why world production may be expected to be well maintained and the downward trend in Canadian output to be less dramatic than recent cost price trends would otherwise lead one to expect.

The outlook for gold production in Canada may conveniently be divided into two parts:

(i) straight gold mines with gold as the main product; these are presently producing between 85% and 90% of the nation's total output; and

(ii) non-ferrous metal mines (mostly copper) producing gold as a by-product; these are currently producing around 13% of the total.

It can be predicted with some confidence that the amount of by-product gold will increase considerably. Stimulated by high copper prices, several new mines of this type have already started production; others are nearing the production stage. Since most copper mines are large-scale longlived

[86]Because of a demand in the late 1940's for gold for hoarding in various parts of the world owing to political unrest and lack of confidence in paper currency, free markets for gold developed in Europe and in the East in which gold was sold at $40 to $45 per ounce, with the supply furnished largely by subterfuge. Pressure by gold producers to be allowed to sell their gold in the free market brought concessions in policy. As a result, the International Monetary Fund (the international organization for the control, exchange, etc. of gold) conceded and new regulations were promulgated by officially allowing some gold producing countries to continue this practice. This raised the supply of gold available to the free markets to 50% of current world production. The effect of this larger supply was a lowering in the price of gold to $37 an ounce by the end of 1952.

[87]Since 1905, South Africa has been the leading gold producing country, followed by the U.S. until 1930 when Canada advanced to second place. (Probably displaced by the U.S.S.R. after 1934.) At the present time, South Africa stands first, the U.S.S.R. second, Canada third, the U.S. fourth and Australia fifth in world production of gold.

[88]See "Gold", a chapter from *Mineral Facts and Problems,* Bulletin 556, U.S. Bureau of Mines, Department of the Interior, 1955.

operations, the amount of gold won from this source should increase steadily and persistently, its rate being little influenced by the world price of gold. Their output, by 1980, might possibly be in the order of one million ounces a year—that is, about double today's production from the nation's copper-gold properties.

Straight gold mines, though the circumstances differ markedly from one producer to another, are in quite a different category. Since there is little incentive to prospect for or develop new gold mines, their number will continue to fall. Falling in half since the industry's peak year in 1941, their numbers will doubtless be further reduced during the 20 to 30-year period under review.[89]

In many existing mines, the tendency will be increasingly toward the high grading of presently proven reserves. Less effort will be placed upon exploration for and the development of medium grade material. Thus the lives of most mines, if not their short-run ability to stay in production, will be progressively curtailed.

The cost-aid plan at present administered by the federal government has had one main effect: it has enabled a number of the nation's relatively high-cost mines to continue in operation longer than they would otherwise have done. Introduced in 1948 and subsequently modified, its provisions have been extended through 1958. It has been estimated from the company cost data available at Ottawa that, should this assistance be discontinued, about 20 mines with a combined production of some 700,000 ounces (or about one-fifth of the output of the nation's straight gold mines) would be forced into a salvage operation, with the likelihood of their closing down entirely in or before 1960.

Alternatively, if the present conditions affecting the industry continue, i.e. a fixed price, a continuation of cost-aid on the present scale and a gradual rise (2% yearly) in costs, it is likely that, by 1980, the production of gold by the straight gold mines will be about two-thirds that of the present with only a continuing decline in prospect.

An even more difficult situation can be envisaged. Should cost-aid be discontinued and our other assumptions remain unchanged, it is altogether likely that the volume of production from the gold mining industry proper would drop to about one-half its present level over the next 25 years. Employment, due to a continuing increase in labour productivity, would then fall more than proportionately.

The following table relating to straight gold mines illustrates these alternative expectations.

[89]The assumption here is that the current price of gold will remain unchanged.

	Year 1954	*Present conditions to 1980*	*No cost-aid to 1980*
Production (fine oz.)	3,823,000	2,380,000	1,980,000
Employment	18,479	7,200	6,000

A considered outlook with regard to gold necessarily takes into account by-product gold production as well. Together, and assuming a continuation of the present government policy with regard to assistance to the more marginal straight gold producers, the outlook is for a 20% to 25% decline in gold output over the next quarter century and a 60% to 70% drop in overall employment.

The following statement appearing in the *Report of the Committee of Inquiry into the Economics of the Gold Mining Industry, 1955,* is worthy of repetition:

> "Canadian gold producers are vitally concerned with the answers to two questions about this peculiar situation: will it continue, and will the United States Government raise the price of gold? In the discussions about the gold problem which have taken place in the United States, the assumption has been universally made that their government would continue its present gold buying policies. In considering whether the United States Government is likely to raise the price at which it buys gold it should be remembered that the gold standard is a gold-price-fixing system and that the only change in the price of gold which has been made in the last century and a half was that made by President Roosevelt in 1933-34 when the United States had for the time being abandoned the gold standard. He hoped that by raising the price of gold a rise in the price of other commodities might be brought about also, thus easing the severity of the price deflation. It is conceivable that in circumstances as serious as those of 1933 such a manoeuvre might once more be tried by a harassed United States Government. To hope for a rise in the price of gold in a period of prosperity is quite another matter. Current proposals for such an increase rest upon complicated arguments as to the effects it might have on the functioning of the world's monetary and trading system. Monetary experts differ sharply as to the need for such a change, most United States specialists being doubtful as to its expediency. Although the continued purchase of gold by the United States Government at the present price can be relied on, it would be most unwise to count upon an early rise in the Washington price of gold.

"It is sometimes argued that were the gold markets of the world freed from restrictions the price of gold would rise much above the Washington price in response to a hoarding demand. It is hard to see why hoarders would be willing to pay more for gold than the United States price plus the cost of moving it from that country. The price in the local currency would of course vary with the price of United States dollars on the local foreign exchange market. Even when exchange or other restrictions narrow the local market for gold the hoarding demand still depends upon the hoarder's belief that gold will keep its value over the years. The hoarders of the Orient have tested the validity of this assumption from time to time by selling considerable quantities of gold. Had government buying not supported the price of gold on such occasions there is little doubt that the price would have fallen considerably. A few such experiences would much reduce the desire of people to hoard gold as a store of value. In other words, the hoarding demand for gold is dependent upon the willingness of some government to buy and to sell gold freely at a fixed price. Apart from such a world-price-fixing system as the United States Government now maintains it would provide a very precarious basis indeed for a high value of gold."

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K. Silver

Silver, like gold, was one of the first metals to be mined in volume in this country.[90] The fortunes of the silver mines, also, have varied considerably down the years. So has Canadian production. Now produced predominantly as a by-product of base metal mining, it is coming back steadily, both in volume and value terms.

This Canadian tendency is by no means an isolated one. With the exception of the world's leading producer, Mexico, and one or two South American countries, the mining of silver as such has largely ceased to be a profitable long-run operation. This has been due mainly to a falling-off

[90]Silver was first produced in Canada at Silver Islet in Lake Superior not far from Port Arthur, in 1866. Later mined in considerable volume in British Columbia and the Northwest Territories, Canadian output rose to record levels after the discovery in 1903 of silver-cobalt ores in the Cobalt district. Output climbed rapidly, reaching 33 million ounces in 1910, a rate which was maintained until the outbreak of World War II. Since then, with the decline of production in Ontario, by-product silver production has become increasingly important.

in price relative to other goods and services. Also it has coincided with the exhaustion of many of the world's major silver producing areas.

Because of its by-product nature, it is possible—given the outlook for the nation's gold, copper, and base metal industries—to forecast this country's output of silver. Lead-zinc mines now produce some 60% of the total; copper-gold mines around 15%; nickel-copper mines around 5%; and the gold mines about 2%. Silver being recovered along with cobalt in the vicinity of the old Cobalt silver mining area, and the much lesser output of silver mined as such in western Canada even now account for less than 20% of the total.[91]

Assuming that production from the latter category of mines were to decline substantially and that the quantity of silver produced along with cobalt were to be reduced, the outlook is still for an appreciable rise in overall production. Using the projections for the other non-ferrous metals, as described elsewhere in this report, a 10% to 20% increase is envisaged over the next decade. By 1980, this may have risen by between 25% and 40% above the quantities being produced in Canada at present. Should this come to pass, Canada's output might well surpass that of the United States, thus placing this country in second position as a world producer of this precious metal.

To anticipate output volumes is one thing; to indicate future values, quite another. The latter presumes, as well, a forecast of prices—something which is a virtual impossibility, having regard to the uncertain role of silver as coinage, government policies and government buying. Of present world production, only a little more than half is consumed in what might be termed industrial uses. The production of sterling articles and its use in photography, silver plating and in the fast growing electrical, electronic and high-performance engine building industries has been rising steadily. Yet, it will be many years before these applications will be sufficient in amount to take all of the new production of the market, let alone absorb the very considerable quantities which might result from any further demonitization of silver metal.

In recent years, the remainder—that is, the difference between world production and industrial consumption—has been absorbed, in one way or another, by governments. Were it not for the United States Treasury's purchases of all the United States domestic silver output and the Mexican government's buying and selling of silver in an attempt to stabilize the market, the price of this metal would undoubtedly be much lower than it is at present.[92] As it is, it has been moving upward, more or less in line with that

[91]There are several predominantly silver-producing mines operating in British Columbia at the present time. Production also has been revived in the Cobalt area in recent years, though principally as a source of cobalt metal rather than of silver as such. Canadian production reached a 41 year high of over 31 million troy ounces in 1954.

[92]Price of silver has varied considerably over the years. Ranging between 50¢ and 75¢ from 1900 to 1914, it rose to over $1.00 in 1919 and 1920. Falling steadily after that, it reached a low of 28¢ in 1932. As late as 1944, it was priced at 45¢. Recently it has passed the 90¢ level.

of other goods and services. The assumption made quite arbitrarily in respect to the future course of prices is that present conditions will prevail throughout the 25-year period under review.

L. Platinum Metals

Canada is likely to retain its position as one of the leading producers and exporters of platinum group metals during the next quarter century. At present producing about 40% of the world's total of new platinum, palladium, iridium, osmium, rhodium and ruthenium metals, output in this country will doubtless expand in step with nickel-copper production in the Sudbury district. As these by-products show no definite trend either up or down in relation to the total quantity of copper and nickel mined in that area, the outlook based on our forecasts for these larger volume metals is for a 25% increase by 1965 and a total rise of about 50% between now and 1980.

A forecast couched in value terms involves a further assessment as to movements of price in recent years. Quotations in respect to these platinum group metals have shown a tendency to move upward relative to other goods and services. World demand, reinforced by a growing number of industrial applications, is continuing to rise. World production, meanwhile, has little more than kept pace with these mounting requirements. The outlook would, therefore, appear to be for a maintenance of present price relationships; possibly with modest variations up and down, depending as much on political as purely economic considerations.

Market breakdown information is incomplete. However, the record in respect to the United States is illuminating. Consumption of platinum metals has trended upward without interruption for several years. Since the mid-1930's, annual quantities for decorative purposes has increased roughly twofold; for industrial uses, approximately fourfold.[93] Because the United States consumes approximately two-thirds of the world's present output and since requirements in other countries may grow more than proportionately in future, demand for Canadian production will doubtless continue strong.

On the world supply side, Canada, as we have seen, is expected to increase its production. Second in line, South Africa, at present produces some 35% of world supplies and also has the resources to make an increasing contribution. This, however, presumes some rise in prices and costs. Meanwhile, output from the U.S.S.R., until 1934 the world's largest producer, may fall behind. The same is true of Colombia in South America. The contribution of all other countries, including the United States proper and the Territory

[93]The platinum metals are being used increasingly in the fast growing electrical and electronic equipment, chemical, and other basic processing industries. Included in the latter category are the catalyst requirements of modern oil refineries and the spinnerets, nozzles, etc. required for manufacturing synthetic textiles, building products like fibreglass, rockwool, etc.

of Alaska, is expected to remain small. Recovery through the collection and reprocessing of scrap, on the other hand, is expected to increase.

The value of Canadian output could be considerably enhanced, not only by an edging upward of real price but also because of further processing in this country. The latter is not, however, considered likely.

At the present time, all of the crude platinum-bearing products resulting from the smelting and refining of copper-nickel ores in this country are shipped to either England or Norway for reduction to metal forms. Returned to Canada, they are subsequently re-exported for further fabrication in the United States and elsewhere. A lesser amount, that contained in copper-nickel matte exported to the United States or the United Kingdom for the manufacture of Monel metal, is never recovered. It is the practice of the industry, however, to use only the lower platinum metal content ores for this purpose. No plans for further processing or semi-fabrication appear to be in prospect.[94]

M. Uranium

(a) *General Introduction*

Among the metals, uranium most typifies change. A laboratory curiosity 50 years ago, it is now being mined in substantial quantities in half a dozen countries. Rejected as a waste product of radium processing as late as 1940, it is already being mined in amounts the gross value of which will exceed that of the precious metals, gold, silver and platinum combined.

Uranium, meanwhile, has ceased to be a scarce commodity. Under the impetus provided by government contracts, output has multiplied many times over. Even in 1950 mining activity was still confined to a few comparatively high or medium-grade deposits in the Belgian Congo, Czechoslovakia, the United States and northern Canada. Since then, as a result of an intensive programme of exploration and development, a number of new and several much larger extensive producing areas have been opened up. Costs meanwhile are beginning to decline. Hence a much larger and even lower cost supply of new metal appears to be in prospect.

In this respect uranium has followed the pattern set by the older metals. First recovered from a few comparatively high-grade ore bodies, they, too, are now being produced from deposits which are better suited to servicing demands of larger and more persistent character. The main difference, however, is one of timing. Instead of these developments taking place over half a century or more, they have been telescoped into less than a decade.

[94]The U.S. imposes no duties on imports of platinum metal in ores or in unmanufactured form but platinum manufactured goods are subject to duties ranging from 25% to 55% ad valorem.

The deposits of uranium which yielded the bulk of the ore produced in prewar days were capable of being selectively mined to produce grades of upward of 1% uranium oxide. These ores were beneficiated by simple mechanical or leach techniques and were valued mainly for their radium content. Since the discovery of nuclear fission in 1938 there has been a complete turnabout in the relative importance of the two metals. Meanwhile, favourable developments in respect to uranium metallurgy have enabled ores with a uranium content as low as 0.1% to be worked at a profit. Some of the more highly disseminated deposits of this latter type exist in the Blind River district of Ontario.

With the aid of specially developed detection devices, uranium finds are becoming frequent occurrences. Though only one in every thousand has been developed to the stage where it can be called a producing mine, proven reserves have risen in remarkable fashion. It is now estimated that three-quarters of a million tons can be recovered at a price of $10 a pound for uranium oxide. As recently as 1948, experts in the industry were talking in terms of one-thirtieth of that amount.

Now that the problem of supply has largely been solved, that of finding adequate markets is receiving greater attention. Defence requirements, though they will continue to take the bulk of the world's uranium production for some years to come, cannot be projected with any confidence beyond 1962. It is therefore to such commercial applications as the production of electricity and process steam that the industry has to look for additional outlets. Yet, because these commercial needs may only develop slowly at first, the possibility of a levelling-off in uranium mine output must be envisaged.

The full economic consequences of this exceptional resource development programme have yet to make themselves felt. Supply is rapidly catching up to demand. Further economies in processing will be achieved. Lower carrying cost will be applicable in the case of fully written-off plants. Increased competition will also help to ensure that the bulk of the world's uranium output will be coming from the most conveniently located and efficient mines. Price reductions, in other words, appear to be inevitable.

As the price of uranium falls, its usefulness as a source of energy is bound to increase. Designers, concerned with the high capital cost of early power reactors, will be inclined to use uranium more lavishly if this in turn leads to savings elsewhere. Fuel cycles may be selected which are more demanding as far as burn-up is concerned. Less exposed material will be returned to the reactors instead of new metal. It may therefore be that the uranium mining industry as in the case of other minerals before it, will be able to turn a period of adjustment to its real long-term advantage.

(b) *Background of the Industry*

Uranium occurs abundantly in the earth's crust. About as plentiful as lead and zinc and about 100 times more plentiful than silver it has, however, been difficult to locate in workable concentrations. One reason is that it is a dispersed element; its minerals tend to occur in widely scattered rather than in readily mined and easily concentrated forms. Another reason is that, until the discovery of nuclear fission in 1938, few had any inkling of its tremendous potentialities as a source of energy.

These twin characteristics of rarely occurring in minable concentrations and of only recently being in worldwide demand have helped to condition both its cost of production and its physical availability. They explain why suitable methods for treating large quantities of extremely low-grade ore had to be developed before uranium mining could become an industry commensurate with that of some of the other metals. They also serve as a reminder that, once there is a large enough demand for a given commodity, price and other incentives sufficient to find and produce the necessary resources are usually forthcoming.

The search for uranium has attracted considerable attention since government restrictions began to be lifted in the late 1940's. Success stories describing the fortunes made by a handful of small operators have become legion, especially in the United States. In Canada, uranium prospecting which has been carried on whole and part-time by people in many walks of life has also stimulated interest in the less accessible parts of the country. Less spectacular, but equally important, have been various developments on the processing front. Solved, some of them in a matter of months, they have been instrumental in bringing uranium into the camp of the medium-tonnage metals, an accomplishment which would have seemed almost impossible a decade ago.

Prior to World War II it was used sparingly as a reagent and as a pigment for the colouring of glass and ceramics. Later, when it was needed in appreciable quantities, only two sources were immediately available to the Allies. One, the Shinkalobwe Mine in the Belgian Congo had been in production more or less continuously since 1921. The other, the Eldorado Mine on Great Bear Lake in the Canadian Northwest Territories, had been discovered in 1930. Both were in remote places. Yet they, together with the tailings of a few vanadium mills scattered over the Colorado plateau in the United States, were the only sources available at the time.

The strategic value of this unique metal quickly received recognition from governments everywhere. Ironically enough, this for a time relegated it to a position of being one of the least sought after of all the metals. In many countries laws were passed reserving to the state prospecting and production rights. Such occurrences as were known to exist were nationalized.

Yet as defence and other needs became more pressing, the question of supply became increasingly acute. Eventually these restrictions were modified to encourage prospecting and mine development under private enterprise.

The United States Atomic Energy Commission, backed by a Congress concerned about a war with Soviet Russia, took the initiative in 1948. The Canadian government owned and operated company, Eldorado Mining and Smelting, acted concurrently. A guaranteed price was posted for uranium oxide in the form of concentrates. Milling and other processing facilities were frequently built using both private and public funds. Overseas, the Combined Development Agency (made up of members appointed by the United States, Canadian and United Kingdom Atomic Energy Commissions) also placed orders for uranium in Belgian Congo, South Africa and Australia.

Meanwhile, extensive investigations were launched with a view to extracting uranium from such low-grade sources as the phosphate rock deposits of Florida and the oil shale formations of Tennessee. As it turned out the tailings (or previously rejected material) of the South African gold mines provided the first major addition to the supply stream. Their average grade (0.033%) and chemical composition proved amenable to the acid leaching and oxide concentration techniques adopted for this purpose in 1950 and 1951. Employing an ion exchange process of precipitation previously used for water purification, new mills were built in most of the gold-producing districts of South Africa.[95] Capable of producing several thousands of tons of uranium oxide annually, they quickly raised that country to first place among the world's producers of uranium concentrates.

It has been said that the 12-month period ending June 30, 1953, marked a turning point in the efforts of the western countries to obtain enough uranium for both defence and power production purposes. Besides the successful operation of the first South African mill, numerous finds were reported in the United States; the Rum Jungle Mine was brought in in Australia and Blind River was discovered in Canada.

In the United States uranium is now being mined in Colorado, New Mexico, Wyoming and Utah. With a projected output of 15,000 tons in 1960, they will place the United States in front of South Africa and Canada. At latest report, reserves in the United States are estimated at 60 million tons averaging 0.25% uranium oxide. Canada with proven potential of at least 225 million tons of 0.105% ore is scheduled to produce a comparable tonnage of uranium oxide in 1959. Published South African reserves are presently the greatest of all; 1,100 million tons containing 370,000 tons of U_3O_8. In sum total and allowing for improved performances in South Africa,

[95]The South African facilities were financed two-thirds from the United States through the U.S. AEC and one-third from the United Kingdom through the United Kingdom Ministry of Supply. Their capital cost has been reported to have been in excess of $200 million.

Australia, the Belgian Congo, France and Portugal, world production may soon exceed 40,000 tons of oxide annually.[96]

There can be little question that more uranium can be found and produced. Much prospecting remains to be done in and around today's source areas. Other areas possess other favourable geographical environments. It must therefore be assumed that as long as the demand for uranium continues brisk, further and further additions will be made to the world's economically recoverable resources.

(c) *Development and Present Structure of the Canadian Industry*

Though uranium was first discovered at Great Bear Lake in the Northwest Territories in 1930 and production commenced in 1933, mining was confined to this area until comparatively recently. It was late in 1950, nearly three years after the Canadian government had announced its intention to throw open the industry to private enterprise, that the first major finds of the postwar period were made. One was at Beaverlodge. Soon afterwards persistent efforts in northern Saskatchewan drew attention to what has since become known as the Beaverlodge Camp on Lake Athabaska. Though most of the ore is lower in grade than that being worked at the Eldorado Mine on Great Bear Lake, it occurs in much greater quantities. At the present time two large and six smaller mines are supplying three mills in this area.

Important as they are these developments were soon to be overshadowed by discoveries in the Blind River district north of Lake Huron. There even more extensive ore bodies have been outlined. Working deposits which bear a resemblance geologically to the great uranium-bearing gold reefs in South Africa have the advantage of being located close by the major industrial centres of North America. Capital costs, for example, tend to be lower than in the more remote uranium mining districts.

In the Blind River district a dozen mines already are, or soon will be, in operation. The majority are equipped with their own mills. As of December, 1956, they represented a capital outlay of close to $300 million. Capable by themselves of treating more than 30,000 tons of ore annually they constitute what is beyond a doubt the largest single uranium mining area in the world today.

In the even more accessible Bancroft area of Ontario, amid geological and other conditions which are unique in the history of uranium mining, three mines and as many mills are also getting under way.

Eldorado Mining and Refining Limited, the Crown owned company which from 1942 until 1948 carried on all uranium operations in Canada,

[96]South African production in 1960 may be about 6,000 tons; Australia 2,000 tons; and France 500 tons.

is the sole buyer. It acts as an intermediary between the various mining companies in Canada and the United States, United Kingdom and other national atomic energy commissions. Eldorado sells at the price it pays the Canadian mines plus transportation and such costs as are incurred in the treatment of concentrates produced in this country. The agreements with the United States authorities provide that the Canadian government may, at any time, divert Canadian production for use in Canada. However, since most of the mines, mills and other primary processing facilities have been financed on United States government contracts, the United States AEC has first call on specific quantities of uranium from Canada. Excess capacity can, of course, be sold bilaterally to other countries. The same situation applies if the United States authorities do not take up their tonnage options.

(d) *Future Requirements for Uranium*

Defence purchases are likely to dominate the market for uranium until 1965 or later. Thereafter, commercial requirements may assume significant proportions. By 1970 the electric power utilities alone may account for 50% or more of the total demand for new metal.

Progress will be made on a number of fronts. The capital cost of nuclear reactors will be progressively reduced. Better design information, the use of less expensive materials and a higher heat rating will help to bring this about. With longer exposures and economies inherent in the mass production of fuel elements, annual makeup costs will also be cut back. Greater system reliability will also help to bring operating expenditures on labour, materials and maintenance down toward those now encountered in the operation of conventional thermal stations, industrial boilers and other coal and fuel oil fired installations. A quarter of a century from now, nuclear units may therefore be under construction in considerable numbers for the generation of electricity, for general industrial purposes and for the propulsion of large oceangoing vessels.

The preponderant reactor type employed at that time will depend in no small measure on the future price of natural uranium. Were that of its concentrates to be reduced from around \$10, as at present, to say \$7 a pound, it would be used much more extensively in single-pass types of reactors. Designers and system planners would be less concerned with the problems inherent in the recycling of exposed nuclear fuels and such units as involve a higher than average holdup of uranium in metal or oxide form would be more likely to be selected for commercial purposes.

Other determinants of world demand in 1980 will be:

(i) the over-all rate of growth in the demand for energy;

(ii) the trend in nuclear power costs relative to those of the more conventional types of plant;

(iii) the amount of uranium required for reactor building purposes; and

(iv) the amount of uranium burned up as fuel.

In another Commission study (see Davis, John, *Canadian Energy Prospects,* Ottawa, 1957) it has been concluded that world fuel requirements will continue to rise at an average annual rate of around 3% (that is, doubling every 25 years). Electric power requirements, meanwhile, may rise more rapidly. Increasing at an average rate of around 7% per year they could multiply fivefold over the next quarter century. In this connection it is also assumed that nuclear power stations, built essentially for base load purposes, will become competitive with coal and oil in Western Europe in the mid-1960's and with the conventional fuels in North America by 1970 or thereabouts.

Were this to be the case, the world's installed capacity might reach 300 million kilowatts 25 years from now. Though some degree of enrichment may be employed, natural uranium will still be the dominant fuel. Breeder reactors, which in total would be even more demanding of new metal, have been discounted for this relatively early development period. So has the possibility that thorium could be introduced in sufficient quantities to substantially reduce the demand for uranium. Meanwhile reactor inventories, inclusive of pipeline requirements, are assumed to range between one and two pounds of oxide per installed kilowatt of capacity. Makeup or current fuelling needs are forecast as being about 0.20 pounds per kilowatt of installed capacity per year.

Using these figures one arrives at a world commercial reactor inventory in 1980 of between 150,000 and 300,000 tons. Assuming, further, that new facilities were being added at a rate of about 10% per year the annual demand for uranium oxide (for inventory building purposes) would then be approaching 20,000 short tons. In addition there is the annual fuelling need. This might approximate 30,000 tons a year in 1980. Altogether (i.e. adding up the inventory accumulation and annual fuel requirements) this adds up to a world demand for oxide of 50,000 tons a quarter of a century from now.

Others have made similar calculations. Though they have envisaged different reactor mixes, their forecasts generally tend, if anything, to be lower than that given above. The Director of Raw Materials of the United States Atomic Energy Commission, Mr. Jesse Johnson, indicated in a paper given in September, 1954, that world annual metal requirements in 1980 would be in the vicinity of 14,000 tons. Five thousand tons of this, he thought, would be required as replacement material on the basis of a 2% fuel burn-up. The remaining 9,000 tons would be needed for fresh plant inventories. This calculation, incidentally, was geared to a 1980 world installed nuclear capacity of 100 million kilowatts.

Various forward looking estimates are contained in the *McKinney Report* (submitted to the United States Congressional Panel on the Impact of the Peaceful Uses of Atomic Energy in January, 1956). An official of the United States AEC's Planning Division, whose opinion was given special mention, indicated that he believed United States requirements in 1975 might range anywhere from 5,000 to 20,000 tons of uranium oxide a year. Mr. Philip Mullenbach, director of Research for the United States National Planning Association Project on the Productive Uses of Nuclear Energy prophesied (in a paper entitled *International Needs and Requirements, June, 1956)* that the world demand for uranium oxide might fall anywhere between 19,000 and 30,000 short tons in the mid-1970's.[97]

While these various forecasts may be substantially overthrown by events they are at one in several important respects, namely that:

(i) commercial requirements for uranium for many years are unlikely to exceed the near-term capacity of the world's uranium mines; and that

(ii) in the decade after 1962, considerable open capacity will exist unless government purchases continue to bolster civilian demand.

(e) *Competition in World Markets*

The Canadian position contains elements both of strength and weakness. That Canada possesses the necessary resources, there is little question. Costs should also be as low as or lower than, those reached elsewhere. On the other hand, there can be no guarantee that Canadian concentrates, oxides or metal will be freely acceptable in all of the major markets of the world. This is not only true of the United States, where a price support programme may be effective for many years, but also applies to Western Europe where exchange considerations and weapon production controls could favour non-dollar sources of supply.

The Canadian mines have an advantage in respect to average grade, available technology and the extent of their development. They may also continue to attract new capital because, being located on the North American continent, their future is regarded as more secure. On the other hand, they have no by-products (with the possible exception of thorium). This is in contrast to mines elsewhere which derive supplementary revenue from the sale of such associated metals as gold, vanadium and columbium. The domestic market also cannot be expected to take more than a fraction of the output of the Canadian mines. (This country's nuclear power requirements, even in 1980, may amount to only about 2,000 tons a year.)

[97]Dr. Chauncey Starr of North American Aviation Inc. recently (April, 1957) prophesied that U.S. commercial needs in 1975 might be in the vicinity of 16,000 tons.

The fact that the Canadian mills and other facilities will largely be written off by 1962 is of little consequence. Similar accounting considerations apply in the case of uranium production elsewhere. Also, the majority of mines in the United States are already assured of United States government contracts running through to 1966. In that they may be in a better position to invest additional capital in improved processing facilities they may, thereby, be able to improve their competitive position over the next decade.

At the present time most Canadian uranium production leaves the country in the form of ores and concentrates. The remainder (about 25%) is processed to metal-grade oxide at Port Hope, Ontario. Technical and economic studies leading to the next step, metal production, are well advanced. However, for the time being, this phase of production will be confined to the manufacture of fuel rods for Canadian use.

Should export markets for the metal develop, and the availability in Canada of a sizable chemical industry makes this a distinct possibility, the sequence may be similar to that followed in the United States and the United Kingdom. The orange oxide of the uranium would be converted, chemically, into one of several uranium fluorides. These, in turn, could be reduced to natural uranium metal or, alternatively, used in the separation of the fissile isotope of uranium, U-235.[98] Smelting, fabrication in rods or pellets and, finally, coating with aluminum or zirconium, are additional steps required in the manufacture of finished fuel elements.

Considerable value is added in each step of this sequence. The production of natural uranium fuel rods (consisting either of the oxides or the metal of uranium) is technically, and may eventually be economically, within the reach of Canadian industry. The manufacture of uranium-235 for enrichment purposes is something else again. Surplus capacity already exists in the United States. The required investment in new plant and equipment is also very large. Only in the event that the Western European countries decide to make themselves independent of an American source of supply is there any likelihood that Canada may become an important producer of uranium metal in this form.

Sight should not be lost of the fact that, in attempting to compete in the fields of metal production and fuel element fabrication Canadian producers will be influenced by the facts that:

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[98]Uranium-235 can be separated from the natural products by pumping uranium hexafluoride, at a tremendous cost in power, through a series of porous screens. This is accomplished in large chambers, the lighter molecule advancing more rapidly than the heavier ones. The more stages, the more complete the separation of uranium-235 from uranium-238. This cascading of gases in which the output of each stage is recycled through the preceding stage calls for great care, a knowledge of related chemical engineering techniques and (of greatest interest to Canada) millions of kilowatt hours of low-cost electricity. This energy is required essentially for pumping of compressed gases. Large amounts of water are also needed for cooling.

(i) plants of a similar type already in operation in the United States and elsewhere will be partly written off against existing government contracts; and

(ii) because these are chemical-type industries, Canada will probably import rather than create for itself most of the technical know-how and equipment necessary to carry on a programme of this kind.

(f) *Conclusion*

The mid-term outlook of the Canadian uranium mining industry is dependent, essentially, upon contracts placed in this country by the United States and, to a much lesser extent, the United Kingdom Atomic Energy Commissions.[99] To the extent that these agencies require Canadian concentrates for their defence programmes the industry will continue to flourish. Commercial requirements, meanwhile, are unlikely to become commensurate with the world's presently planned mine capacity until 1970 or later. Even greater uncertainties surround the production of uranium metal either for enrichment purposes or in rod form. Tentatively however, it has been assumed that Canadian production of uranium concentrates will be valued at approximately $300 million; and the value added by converting part of this material to high purity uranium oxide, uranium fluoride, natural uranium metal, and separated U-235 and plutonium will approximate $250 million 25 years from now.

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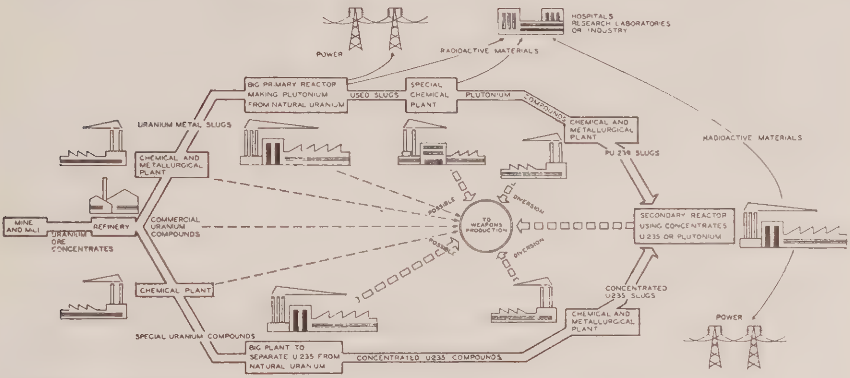
[99]Until 1962 or 1963 Canadian output will probably be sold about 93% to the U.S. AEC and 7% to the U.K. AEA.

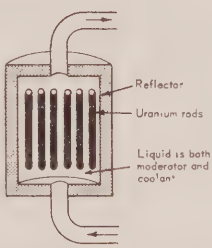
THE PROCESSES USING URANIUM TO PRODUCE ATOMIC ENERGY



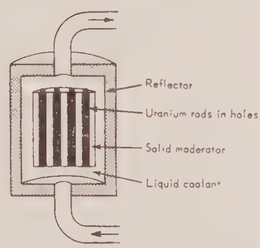
NOTE WASTE PRODUCTS FROM THE VARIOUS STAGES IN THE PROCESSES MAY BE REPROCESSED TO RECOVER THE URANIUM OR PLUTONIUM WHICH THEY CONTAIN. FOR SIMPLICITY SUCH OPERATIONS HAVE NOT BEEN SHOWN

FIVE REACTOR COMBINATIONS

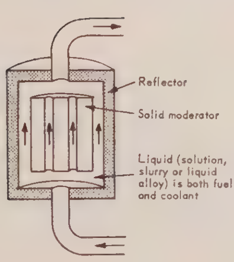
Nuclear fuel, moderator, fertile material and heat-transfer fluid may be combined in various ways. *Homogeneous* reactors have fuel and moderator mixed. They are separate in *hetrogeneous* units.



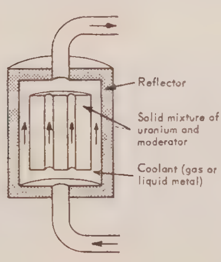
HETEROGENEOUS REACTOR uses solid fuel, liquid moderator serves also as a coolant.



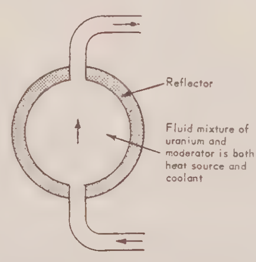
HETEROGENEOUS REACTOR has uranium slugs or rods in solid moderator, separate coolant.



HETEROGENEOUS REACTOR: solid moderator; liquid fuel is both heat source and coolant.



HOMOGENEOUS REACTOR has solid mixture of uranium and moderator, coolant circulates.



HOMOGENEOUS REACTOR. circulating mixture of fuel and moderator acts also as coolant.

N. Other Metals

(a) *Less Common Metals*

(i) Beryllium	(vii) Molybdenum
(ii) Cadmium	(viii) Niobium
(iii) Chromium	(ix) Selenium
(iv) Cobalt	(x) Tellurium
(v) Manganese	(xi) Thorium
(vi) Mercury	(xii) Tungsten

Various other metals, several of which could become of much greater importance to the Canadian economy have been listed above. They are not necessarily scarce. Indeed, they are often called less common because they are required only in small quantities. Strategic rather than cost or other value considerations weigh heavily in their development and use.

The fact that their production is of modest proportions may, on occasion, be due to difficulties encountered in their mining and extraction processes. More often it is a lack of suitable applications which has tended to set an upper limit on their output. The role which they play is, however, expanding. Without the less common metals there would be many fewer alloys of steel, no high temperature super-alloys, no suitable electronic mechanisms and no prospect that nuclear energy could be produced economically from such sources as uranium and plutonium.

Yet forecasts are out of the question. Many of these metals are only now entering the industrial scene. Separately or combined with other elements they possess a host of properties only a fraction of which have been investigated let alone, applied. Like uranium in the 1930's, one or two may suddenly come into its own. They may include one or more of the major product Xs of the next quarter century. Here all we can do is review some of the possible uses which they may be eventually called upon to fulfil.

(i) *Beryllium*

Beryllium occurs in a number of widely scattered deposits in Canada. These, however, are not commercially exploited at present. One of the reasons is that the world consumption is still small (12,000 short tons in 1956). Should this grow and North American consumers continue to utilize 40% or more of the total the incentive to produce beryllium metal in this country would be enhanced.

Beryllium metal has an unusually favourable combination of properties such as a low density (1.84), a very high modulus of elasticity (40 mill. psi), high melting point (1,285°C) and satisfactory corrosion resistance. Unfortunately, limited supply and fear of dangerous health hazards are keeping beryllium from becoming a more common metal.

The most important uses of pure beryllium are as reflectors and moderators in the nuclear energy field, in inertial guidance mechanisms for guided missiles and aircraft, windows in X-ray tubes, etc. The use of beryllium and beryllium-base alloys is under active investigation for potential applications in aircraft structures. Other applications include the use of beryllium as an alloying agent in copper, nickel and iron alloys; small additions to aluminum and magnesium alloys; use of beryllia in the refractory field; etc.

It seems that considerable expansion of the beryllium industry is assured. The main problems to be solved are related to the high cost of beryllium products and to the prevention of exposure to the toxic effects of beryllium compounds.

(ii) *Cadmium*

World production of cadmium is now in the order of 9,000 short tons annually. Canada is well up the list, being the second largest producer with a yearly output of metal approximating 1,000 tons. Its value in 1955 was approximately $3.5 million. Over 80% of this output was exported.

Since cadmium production is only a by-product of zinc, zinc-lead or zinc-copper smelting, its future is closely connected with the trends in the zinc industry. Canadian output of cadmium will, therefore, increase roughly at the same rate as zinc production. Demand, however, may be more elastic and will depend on future developments of some of its applications, especially in the nuclear energy field.

About 60% of cadmium metal is used in electro-deposited protective coatings on steel and some copper alloy products. Other uses include nickel-cadmium storage batteries; cadmium-base bearing alloys for service at high speeds and temperatures; low-melting fusible alloys and solders; as an alloying element in copper, lead and some aluminum alloys; etc. In the field of nuclear energy, cadmium is being used for shielding purposes and in reactor control; another modern application is in solar energy generators. Non-metallic uses include various pigments for paints, inks, ceramic glazes, paper, rubber, glass, etc.

Substitutes exist for cadmium in a number of its applications. On the other hand, further research aimed at the development of cadmium additions to aluminum and mangnesium base alloys is warranted. Should the potentially large use of cadmium in nickel-cadmium storage batteries materialize, this could place an additional strain on the already limited supplies of cadmium available to industry.

(iii) *Chromium*

Though Canada possesses no deposits of commercial grade ore, some chromite was produced in eastern Canada during World War II. Deposits

in the Lac du Bonnet district of southeastern Manitoba are large but too low in grade to warrant recovery at present. Yet an increase in price or advances in mining and process technology could render their production economic. Besides, there is the ever-present possibility of discoveries being made of higher-grade chromite deposits in Canada.

Canadian consumption of chromite amounted to some 50,000 short tons in 1955. Valued at $970,000 these imports were used for the production of ferro-alloys by Electro Metallurgical Co., Division of Union Carbide Canada Ltd. at Welland, Ontario, and by Chromium Mining and Smelting Corp. Ltd. at Sault Ste. Marie. Canadian Refractories Ltd. produces chrome refractories at Marelan, Quebec.

The principal uses of chromium are in the fields of ferrous metallurgy, high temperature resisting alloys and plating. It is very important in stainless steels to increase their heat and oxidation resistance. Chromium is used also to improve the hardening qualities of ferritic steels and, to a lesser extent in cast iron where it increases hardness, strength and resistance to oxidation and growth at higher temperatures.

Chromium-base and high-chromium super-alloys are used for various components for service at high temperatures in jet engines and guided missiles. Considerable amounts of chromium are used in protective and decorative plating of steel and various other metals. Smaller amounts are used in alloying of copper, nickel and aluminum.

Expanding uses for chromium and approaching depletion of the world's high-grade ore reserves necessitate a large-scale stepping-up of development work on the utilization of low-grade ore. Because of its importance for the steel industry and the exceptional characteristics of high-chromium alloys, it seems that a considerable expansion of the chromium industry will take place in the next 25 years.

(iv) *Cobalt*

Canada is the world's second largest producer of this metal. In 1956 some 1,850 short tons of cobalt metal valued at $9.4 million were produced in this country. Over two-thirds of the total was exported, principally to the United States. Production in Canada takes the form, mainly, of a by-product in the refining of nickel ores mined in the Sudbury Basin, at Lynn Lake and with silver at Cobalt-Gowganda. Production of cobalt ores as such from the last area is normally dependent upon an incentive price such as exists during emergencies. Consumption of cobalt in Canada is at present about 150 to 200 tons a year.

In the steel industry, cobalt is used in high-speed tool steels, in permanent magnet steels, in high temperature die steels and in various alloys for corrosion and oxidation resistance.

The most important application of cobalt is in the field of high temperature super-alloys used in modern jet engines. Cobalt-base alloys are used mainly as castings, sometimes as forgings. Other important uses include Alnico magnets and hard-facing alloys. A radioisotope, Cobalt 60, is used widely by industry for radiographic examinations and in the Cobalt Bomb for cancer treatment. Cobalt compounds are used in ceramics and glass manufacture, as driers in paint, varnish, enamel and ink, and in animal feed nutrition.

The continued expansion of the nickel industry will no doubt mean a corresponding increase in by-product production from this source. The enormous expansion of high temperature materials seems to guarantee a very bright future for cobalt

(v) *Manganese*

Canada produces no manganese ore, although large low-grade deposits are available and a small amount of bog manganese has been mined in past years from deposits of New Brunswick. At the same time the availability of abundant and cheap power has enabled the establishment of a modern ferromanganese plant at Welland, Ontario, operated by Electro Metallurgical Co., Division of Union Carbide Canada Ltd. Metallurgical grade manganese is also used by Chromium Mining and Smelting Corporation Ltd. at Sault Ste. Marie to make manganese alloys.

Strategic Materials Corporation Ltd. recently opened a pilot plant at Niagara Falls to process low-grade manganese ore from the Woodstock, New Brunswick area, using the Udy-process. A full-scale processing plant to be built at Woodstock, N.B., has been announced by the same company. Other potential sources for manganese are the large reserves of manganiferous iron ore in Labrador and New Quebec, as well as the manganese containing paint-rock at Steep Rock.

About 95% of manganese is used in the steel industry, where it acts as deoxidizer and cleanser of steel, especially to counteract the adverse effects of sulphur, thereby greatly improving the hot-working properties of steel. It is used also as an alloying element to improve strength, toughness and response to heat treatment of a variety of structural and engineering steel. Austenitic (high-) manganese steels are used for their excellent wear resistance under impact conditions. They are used very extensively in the mining industry, wherever hard materials are to be dug, crushed or handled.

Manganese is being partially substituted for nickel in some grades of stainless steels. If this use increases in the future, it may release a certain amount of nickel for other purposes.

Most of the manganese consumed by the steel industry is in the form of ferromanganese, silico-manganese, spiegeleisen, manganese metal and ore,

in the order given. Electrolytic manganese metal is used in stainless steels, thus eliminating the need of a carbon stabilizer.

In the non-ferrous field manganese is used in aluminum, copper, zinc, nickel, magnesium and titanium base alloys. Electrolytic manganese is used for manganese-base and high-manganese copper-base alloys developed by the U.S. Bureau of Mines. Considering the wide availability and its relatively low cost, all indications point to a considerable widening of the field of manganese applications in the non-ferrous metals industry.

Since most of the sources of high-grade manganese ore are either behind the Iron Curtain or depend on vulnerable shipping lanes, Canadian resources could receive greater attention. Process development is the key. Should the Udy-process prove commercially competitive, North America could become self-sufficient in this respect.

(vi) *Mercury*

There has been no Canadian production of mercury since 1944 when special wartime contracts were in effect. Domestic requirements, as formerly, are covered by imports. The principal Canadian deposits of cinnabar (mercury sulphide) are in British Columbia. Though low in grade they are capable of supplying Canada's requirements for many years should this become necessary.

Metallurgical applications include the use of mercury in the Mercast precision casting process; in amalgam metallurgy where mercury is used for reclaiming metals from mixtures, such as the separation of bismuth from lead, refining thallium, treatment of zinc scrap, extraction of gold, etc.; in solders for galvanized iron, etc. Other uses include industrial and control instruments, electrical apparatus, mercury-steam turbines, mercury-arc rectifiers, and many others.

(vii) *Molybdenum*

Shipments of molybdenite from the sole Canadian producer, Molybdenite Corporation of Canada Ltd., amounted to 726 tons in 1956 (valued at $967,500).This output is the second highest ever recorded in Canada the exception being the year 1944 when 935 tons were produced. Formerly all of this molybdenite production was exported, there being no processing plant in Canada until December, 1956, when the aforementioned producer commenced molybdic oxide production at La Corne Township, Quebec. Canadian consumption of about 425 tons of molybdenum contained in alloys would be more than met by the above concentrate production if they were converted to suitable addition agents.

In the steel industry, by far the largest consumer, molybdenum improves

considerably the hardenability of alloy steels, increases their strength up to

400°C and is used in high-speed tool steels and, to some extent, in cast irons.

Molybdenum or molybdenum-base alloys are potential materials for high temperature service, having excellent strength up to some 1,500°C but must be protected by coatings impervious to oxygen. Siliconizing of molybdenum products seems to be very successful up to 1,650°C, giving a hard and integral binding. Unlike ceramic coatings siliconized coating is a conductor, so that electrical contact can be made through the coating.

Other uses include electronic tubes, various applications in the chemical industry, large electrodes for glass melting furnaces and many more.

With ever increasing requirements for engineering materials having adequate mechanical properties at ever higher temperatures, further development of molybdenum applications in the next decade is assured and reserves should be ample for some time to come.

(viii) *Niobium (Columbium)*

Production of niobium in Canada has been of minor importance to date. However, small quantities have been produced intermittently from pegmatitic rocks in the Northwest Territories. During the past few years many large deposits of pyrochlore have been found, situated at Oka, Quebec; Nenegos, Ontario; Lake Nipissing, Ontario; and Golden, B.C. The estimated niobium pentoxide content of these reserves is in excess of 500,000 short tons, 100 or more times the 1955 world production figure of 5,600 short tons of combined Ta_2O_5 and Nb_2O_5. However, these pyrochlore deposits are generally of a very complex character and a considerable amount of research work remains to be done before any large-scale commercial production can start.

The principal use of niobium is in the steel industry. It is used (in the form of ferroniobium or ferrotantalum-niobium) in stainless steels where it serves as a carbide stabilizer and prevents intergranular corrosion at high temperatures. It increases also the elevated temperature strength of high-alloy steels.

Other uses are in high-temperature alloys for jet engines and in the nuclear energy field as canning material and as an alloying element in uranium metal.

The discovery of ample resources of niobium (actual reserves of niobium in North America exceed the combined total known reserves of nickel and molybdenum) and the increased applications in vital industries, having occurred together, may lead to a considerable increase in niobium production during the next quarter century.

(ix) *Selenium*

Canada is the second largest world producer of selenium with an annual production of approximately 250 short tons in 1956 (valued at $6,858,000), of which about 200 tons (valued at $6,342,748) were exported.

Canadian Copper Refiners Ltd., Montreal East, operates the world's largest selenium plant, with a rated annual capacity of 225 short tons. Selenium is recovered from the electrolytic refining of copper anodes produced at the Noranda smelter, from copper ores in the Noranda area, and from blister copper produced by the Hudson Bay Mining and Smelting Co. Ltd. in Flin Flon. A second selenium plant, rated at 135 short tons annually, is operated by the International Nickel Co. of Canada Ltd. in Sudbury.

The principal uses of selenium are in the manufacture of dry-plate rectifiers for radio, television and signal equipment, and of photoelectric cells, in the colouring and decolouring of glass; in promoting heat, oxidation and abrasion resistance of rubber; as antioxidant in lubricating oils; as a catalyst in the synthesis of organic chemical and drug products; etc. Ferro-selenium (50%) is used in the production of stainless steels. Other metallurgical uses include the addition of selenium to copper alloys to improve their machinability without impairing their electric and hot-working properties, and as coating on steel and magnesium alloy products.

A continuing worldwide shortage of selenium has caused the search for new sources of selenium to be intensified. Although there is some possibility of recovery of selenium from sources other than copper smelting products (e.g. from plants growing in seleniferous soils), it seems that it will remain scarce for some time to come and that there will be a constant upward pressure on its price. Canadian selenium production can, therefore, expect a steadily increasing market both in terms of volume and value.

(x) *Tellurium*

Tellurium is a by-product from copper and lead refining. Hence Canada is a major producer of tellurium with an annual production of 12 short tons in 1956, of which most was exported.

Major uses of tellurium are in alloying additions to lead (to refine the grain size and increase hardness, strength and corrosion resistance), copper (to improve machinability without significant loss in thermal and electrical properties), to steel (to improve machinability), and to white-metal bearing alloys (to increase strength). Other uses are in the rubber industry and as colouring agent in glass and ceramics.

The demand for tellurium is limited and producers usually have substantial stocks on hand. Research under way indicates that tellurium has very desirable semi-conductor properties and future uses in the electronics

field could be promising. Endeavours to substitute tellurium for selenium have been, in general, unsuccessful because of the garlicky odour caused by tellurium

(xi) *Thorium*

A large potential reserve of thorium exists in the Blind River uranium field. Though the content is very low, it could—given a sufficient price incentive—be extracted from the waste liquors presently being discharged from the uranium mills and concentrators in that area

The future demand for thorium is tied up closely with nuclear plant technology. Thorium, in this connection, is a potential substitute for uranium. Equally fissionable and capable of standing much longer exposure times it may eventually become a favoured fuel in mature nuclear power systems.

Present limitations to its use arise from the fact that thorium can only be introduced progressively into what must initially be pure uranium and uranium-plutonium reactor cores and blankets. Only after five to ten years could it be introduced in appreciable quantities. Thereafter, it could be employed more and more in place of uranium. The resultant systems would then be mainly U-233, thorium in character.[100] Thorium, in other words would be the only ingredient required for make-up purposes.

The principal non-nuclear use of thorium is as alloying addition to magnesium alloys, improving considerably their strength and creep resistance at elevated temperatures up to 400°C (750°F). These alloys are used extensively in jet aircraft and guided missiles. Thoria refractories are gaining in importance.

(xii) *Tungsten*

Tungsten production in Canada in 1956 was derived almost exclusively from Salmo, B.C., operations of Canadian Exploration Ltd. and shipments amounted to 1,100 tons of WO_3 content (valued at $6 million). Because of the fact that production from this source was sold to the United States stockpile from 1952 until around the end of 1957 at a price of approximately three times the current market price for scheelite, it is probable that production will be at a lower level in future years. There are no other known commercial deposits of tungsten in Canada. The consumption of tungsten as metal, carbide, wire and ferrotungsten used in Canada amounted in 1956 to around 140 tons.

The principal use of tungsten (about 90%) is in the steel industry, especially in high-speed tool steels, in die steels for hot working or brass

[100]It has been forecast that, by 1975, some 11,000 tons of thorium will be required in nuclear reactors in the United States. See: "Thorium's Role in Atomic Power", by J. P. Howe, *Metal Progress 71*, February, 1957.

die casting, in tungsten magnet steels, in valve steels and various other heat and corrosion resistant applications.

Tungsten carbide is used for cutting tools; wire and tube drawing dies; for various wear-resistant parts such as gauges, valve seats and valve guides; and as cores in armour-piercing shells.

In the non-ferrous super-alloy field, tungsten is used in varying amounts to produce hard-facing, heat-resistant and corrosion-resistant alloys, mainly for turbo-jet engine components, heat exchangers, superchargers, etc.

Other applications of tungsten include filaments for incandescent lamps, electronic parts and targets for X-ray tubes, welding electrodes, etc. There is also a growing tendency to use tungsten alloy for containers for radioactive isotopes and for radiation shields in general.

The future of tungsten, the most refractory metal used commercially, seems to be bright although considerable research is still necessary to develop appropriate applications.

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(b) *Tin*

Tin is the only non-ferrous base metal not available in Canada to any significant extent. The geographic distribution of the tin ore reserves and the political vulnerability of tin supplies, as well as its high price, make it necessary to limit as much as possible its uses and to encourage research to

find substitutions for as many as possible of the present applications of tin. Work in this direction was started during World War II and continued during the Korean emergency. Many of these substitutions were found satisfactory and became permanent replacements.

However, in such applications as tinplate, solders, Babbits, etc., the use of tin is still very much favoured and seems likely to increase with the growing industrial expansion. There are also some new applications, including aluminum-tin bearing alloys, tin-zinc and tin-nickel plating, copper-manganese-tin alloys for cutlery, etc.

Tinplate is by far the largest consumer of tin.[101] It is being forecast that aluminum will be a very close competitor in the food and beverage can field, particularly if the latest developments in aluminum impact extruded products and aluminum joining methods are successful. In collapsible tube and foil applications, aluminum products have already almost completely replaced tin and lead. Tin consumption in bronzes and in bearing alloys is also on the decline.

Canada's tin consumption is based almost entirely on imported tin and it is essential to have a reasonable stockpile of tin available in case of an emergency. The world supply of tin is tight at present but it seems that the situation would change very rapidly, whenever the United States government stops its stockpiling programme, which at present takes an estimated 14% of the world's production.

Canada's only production of tin comes from the treatment of lead-silver-zinc ores from the Sullivan Mines, at Kimberley in southeastern British Columbia. Here the annual output of tin varies from 100 to 400 long tons of metal contained in concentrates. This is currently exported for refining and the metal is returned to the parent company, Consolidated Mining and Smelting Co. Ltd., for distribution.

Tin occurrences of mineralogical interest are widely distributed across the country, but of special interest is an area near Bathurst, New Brunswick, where the lead-zinc ore of Brunswick Mining and Smelting Corp. Ltd. is reported to contain tin. There is also an area east of Dawson City, where alluvial sands are reported to contain cassiterite, the principal ore of tin. Here, future exploration also affords interesting possibilities.

Imports of the metal amount to about 4,500 short tons annually, all for internal consumption. This average has not varied much over the past few years although the trend appears to be upward, with 4,800 short tons

[101]Pattern of tin consumptions by end-use in Canada and the U.S. is reported to be as follows:

	Canada 1955	U.S. 1955	U.S. 1946
Tinplate and tinning	48%	40%	32%
Solders	38%	24%	20%
Bronze and brass	4%	22%	28%
Babbit	6%	5%	10%
All other uses	4%	9%	10%

estimated for 1957. Large quantities of tin are used in making solders and Babbit, and the growing tinplate industry, with its expanding applications for food and beverage containers, is consuming increasing amounts. Appreciable amounts are also used by tinning plants which hot dip a variety of steel utensils used in the dairy industry and in the home for cooking. Smaller quantities are used in making tinfoil and in a variety of chemical compounds.

Two steel plants located at Hamilton are capable of producing sufficient tinplate to satisfy the growing demand for tin cans, while requirements for tin alloys are adequately handled by secondary metal refineries and foundries located in the larger cities throughout the country. In a similar way the tinning plants are able to deal with national requirements of tinware, although this industry considers that it needs protection against imports by international retail merchants (chain stores), who buy large quantities in depressed areas and retail across Canada.

World production at the mine and smelter stages has declined from 1954 production levels while consumption has been increasing since 1952. Production in recent years, however, has been in excess of consumption requirements but the tendency toward oversupply has been countered by national stockpiling, particularly in the United States. It is reported that the United States stockpile has now reached 400,000 tons (seven years' normal requirements) and that the programme is now completed. It is possible, as a result of these offsetting influences that production and consumption may be roughly in balance over the next few years.

Nations interested in production and consumption of tin have united in an effort to formulate and administer the International Tin Agreement which aims at maintaining adequate tin supplies and at controlling prices within predetermined limits. Canada is an active member of the Agreement and, being a consumer, is interested in obtaining metal on reasonable terms. This interest, in sympathy with other consumers, stems from having the principal resources concentrated in a few source areas remote from the world's principal centres of consumption.

The resource countries, in order of importance, include Malaya, Indonesia, Bolivia, Nigeria, Belgian Congo, Thailand, Siam and Burma, the first five of which are members of the Agreement. On the consumer side, the United States has singularly elected to remain outside the plan. The Agreement became officially operative in July, 1956.

The difficulties experienced by consuming countries in obtaining tin, particularly in time of war, has led to extensive research to find substitute materials and develop techniques to cut down or circumvent the need of tin. This work has been rewarding, particularly in the development of thinner tin coatings for tinplate. Its application in the canning industry has resulted in the development of lacquer coatings to augment the tin. The

industry has also developed a method for sealing steel cans with only a thin tin coating on the sealing edge and in this way the can manufacturers can almost eliminate tin. However, it is significant that the costs involved in applying this technique do not promote general use, and, as long as tin supplies are available at reasonable prices, its competitive position is not seriously threatened. Such materials for containers as plastics, aluminum and fibre are being successfully used to package a wide variety of products; but, in spite of the inroads made by these, tin has sufficient unique qualities to make it indispensable and is usually more economical than substitute materials. Solders, too, used in a wide variety of applications in the electrical and other fields, need tin in large amounts; and while the consumption can always be cut in time of shortages, manufacturing costs usually increase.

The world demand for tin may therefore be a gradually expanding one. Consumption is expected to increase slowly but steadily, and mining activity, both exploration and development, may need special attention to maintain ore reserves. However, no insurmountable difficulties are foreseen in either supply or demand and these will likely be kept in balance. Canada can be expected to keep pace with the rest of the world, and in so doing, may be expected to consume an estimated 7,000 short tons by 1980. Domestic production, though modest by comparison, may gain relative to this country's industrial requirements.

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O. Asbestos

(a) *General Introduction*

Asbestos continues to lead by a considerable margin all other industrial minerals produced in Canada. Its value of production is currently in the order of $100 million; that of gypsum, the next non-metal in line, is $7 million. All of the Canadian-produced industrial minerals[102] together were valued at $145 million in 1955. These statistics, together with the fact that 95% of the nation's asbestos output is exported (and is therefore an important earner of foreign exchange) underline the important part played by this industry in the Canadian economy.

Since the 1880's Canada has been the world's principal source of this comparatively rare mineral.[103] Furthermore, her leading position, while it could be challenged, is unlikely to be surpassed during the quarter century under review. Only one country, Soviet Russia, appears to possess resources which are comparable in quantity. The productive potentiality of Southern Rhodesia is also great, especially for large tonnage exports of short fibre asbestos if future markets are developed of economic interest to this source of supply. Production in others, while inclusive of certain highly prized grades and qualities, is likely to remain small by comparison. Also, Canada, because of opening up of new properties and the strong commercial ties which her asbestos mining industry enjoys with fabricators elsewhere, is likely to have available to her both the market incentives and financial resources necessary to support an expansion programme comparable to, if not much greater than, that experienced elsewhere.

Here is another industry whose base is both broadening and deepening. Asbestos is being used increasingly in applications which themselves appear to be growing at a greater than average rate. It is being employed increasingly in the construction industry and especially in cement and plastic products. It is a vital material in circumstances where high temperatures are normally encountered. Thermal power plants are an example. The electric utilities will therefore make increasing use of this strategic commodity. The manufacture of industrial equipment, especially that of a mobile type, is making ever heavier demands on asbestos. Defence requirements, in that they are also characterized by high temperature developments of one kind or another, are also continuing to take a sizable proportion off the market. The use of short fibre grades has penetrated a number of manufacturing

[102]Excluding structural materials, stone, sand and gravel, lime, cement and clay products.

[103]The discovery of asbestos in the 70-mile strip of serpentine rock in the Eastern Townships of Quebec, stretching from East Broughton on the east to the town of Asbestos on the west, is generally agreed to have been made about 1874. In world commerce the term asbestos is applied to several fibrous minerals. Of these, chrysotile alone is produced in Canada and other varieties required for Canadian consumption are imported. Crocidolite and amosite for the Canadian manufacturing industry are imported from the Union of South Africa. Amphibole fibre, such as tremolite, is imported from Europe. There may be a small amount of another variety, anthophyllite, imported from the United States. Of total world production of asbestos, at present in the order of 1.7 million short tons of all grades and varieties, Canada produces about 60%; the Soviet Union, 16%; Union of South Africa, 8%; Southern Rhodesia, 7%; the United States, 4%; and Swaziland, 2%. The total value of world production, exclusive of Russia and its satellites, was approximately $130 million in 1953.

processes. It has been accepted as a fibrous filler with a large tonnage market growing for it more rapidly than for the long fibre varieties. These grades are now used in products as diverse as moulded plastic articles and insecticides. These considerations, together with the fact that asbestos would probably be used in even greater volumes had additional supplies in the postwar period been more readily forthcoming, lends confidence to the view that past consumption trends can be used as a general guide to the level of future requirements.

There is always the possibility of substitution. Other products, and particularly the glass fibres, have been introduced in certain applications formerly served exclusively by asbestos. Improvements in design have also served to minimize the amounts required for certain purposes. Concerted attempts are continually being made to produce asbestos artificially. Though they have been singularly ineffective to date one cannot rule out the possibility. This may limit some of the demands which might otherwise have an impact on this industry.

However, cognizance should also be taken of the peculiar physical properties of this mineral which are important to the development of future uses. Chrysotile is a natural occurring inorganic fibre with each fibril .0000007 to .00000118 inches in diameter. The fibre diameter of glass, on the other hand, in the present industrial limit of that art is .00026 inches. The chrysotile fibres are strong, in the order of 100,000 pounds per square inch, resistant to heat, and although becoming brittle at high temperature they retain their shape until stressed. They are extremely flexible and are considered by some authorities to be hollow cylinders. Although certain substitutes on occasion enter the field of application of this mineral, none has been offered of identical characteristics.

Research to more fully exploit the latent physical properties of the mineral is certainly in progress in the United States and probably elsewhere.[104] The industry has been a Johnny-come-lately in this field but is now quite conscious of the need for research to ensure markets of the future for products from asbestos. The largest producer, Johns-Manville Corporation, which uses asbestos in some manner in most of its products has in operation at Manville, N.J., a large research organization.

[104]The grading system in use by Canadian producers divides the product of the asbestos mills into seven major categories according to length, ranging from the longest (Crude No. 1), to the very short fibres classified in the trade as refuse and shorts. Most of the major groups are divided into several sub-groups. The proportions falling in the several grades are fairly constant for any one deposit; and, as the miner has to take the rock as it comes, he has little control over the proportion of the various grades in his output, beyond the scope possible in manipulating the milling process.

The demand, at any one time, may be stronger for certain grades than for others. Sometimes the mine operator must, in consequence, accumulate a sizable inventory of the less salable types; either that, or sell them at sacrifice prices. Success in the asbestos mining industry, therefore, depends to a large extent upon the development of a balanced market—a number and variety of customers who will absorb all grades, roughly in the proportion which they are produced. In recent years the demand for practically all grades has exceeded supply and, therefore, the difficulties involved in market balancing have been minimized. Research by the producers in recent years has been directed toward increasing use of short fibre grades by industry. Continuation of this trend will serve to extend the recovery of millable asbestos from its ore.

The total market for asbestos continues to grow. At one time only the longest and best fibres were used to make a limited range of high-priced articles. Now even the lowest-grade material can find a market. Much larger volume applications, particularly in the construction field, are being served. The industry, in other words, is becoming a much larger tonnage operation. Also, because of the increasing diversity and relative stability of its markets, it is less vulnerable than it once was. Though it is far from being one of the more predictable of commodities, there appears to be good grounds for expecting it to continue to grow at least as fast as, and probably faster than, most of the other mineral commodities which are produced in quantity in this country.

(b) *Long-Run Market Trends*

Looking back over the past 20 or 30 years, world consumption appears to have been rising at a rate in the order of 5% per annum; doubling, that is, every 12 to 15 years. Regionally there appears to be little variation. North American requirements and those of Western Europe, despite the interruptions caused by World War II, appear to have moved upward together. The same broad generalization does not, however, apply to all grades and species. Reflecting the greater use made of shorts and floats, consumption of the longer and higher-priced fibres has tended to fall behind that of the categories formerly rejected along with the waste rock.[105]

Though supply, rather than demand, has been the main determinant of this growth, the use pattern has also been changing. Originally confined to the manufacture of textiles and steam packings, asbestos has begun to be used more and more by the electrical, other machinery and equipment, building and construction industries. The processing of plastics, too, finds increasing use for this rock substance which can be spun into yarn or blended with synthetic materials in order to increase their strength under a wide range of chemical and physical conditions.

The electrical industry is using more asbestos in the form of woven tapes and high-temperature insulation felts. The motor vehicle and other automotive and industrial equipment manufacturers find it essential in the manufacture of clutch facings and gaskets, and where braking requirements are particularly exacting. The chemical industry has little choice other than to use it where gaskets and packings are subject to considerable variation in temperature and in circumstances where maintenance costs would otherwise be prohibitive. With regard to the production of building materials, asbestos, particularly the medium grades, is being mixed increasingly with cement to produce flat and corrugated siding and pipe. For years it has been employed along with asphalt in the making of roofing, floor cover and caulking

[105]In recent years the percentage of short fibre grades produced has been increasing until they currently represent 65% by weight of the fibre shipped and 35% by value.

materials. Plastic products including floor tiles and paint now incorporate asbestos. Special papers and millboard are essential to certain types of construction, particularly to those of the industrial variety.

These are, interestingly enough, growth industries. That is to say, they are expanding at a rate at least equal to and even greater than the rest of the economy. Were their utilization of asbestos to continue at its present intense demand, it too could be expected to move upward at a rate in excess of the G.N.P. of most countries. A rate of 3% per annum, following such reasoning, would seem to be an absolute minimum so far as these existing applications are concerned.

Reference has already been made to the possibility of substitution. One effort, for example, has already been directed toward the replacement of asbestos by glass fibres. The supply of Canadian spinning grades was extended considerably during World War II by making fabrics containing a blend of both materials. Although such products are still being manufactured, their use is severely limited and offers no serious competition to the market for Canadian spinning fibre. It is reasonable to expect, however, that other areas of application may witness some form of substitution as time goes by.

There seems to be a limit to the invasion of markets now held by asbestos, however. Neither glass filaments nor cloth woven from them are as resistant to high temperatures. They are less flexible and more susceptible to fracture under constant strain. Such metal fibres as steel wool, or organic substances including the chemical plastics and cellulose, have the added disadvantage of being more subject to corrosion. It seems likely, therefore, that the extension in use of these alternative substances will continue to be in low and medium-temperature applications where continual durability in the mechanical sense and resistance to chemical effects is not of primary importance.

The spectre of synthetic asbestos has always been present. Research is continually being carried out with this aim in mind, especially in the United States, where the desire to be independent of external sources of supply is great. Limited progress has, however, been made toward this objective. Though asbestos fibres have in fact been grown from inorganic solutions, the problem remains one of making fibres in quantity and of adequate size and length. For purposes of our own forecast it has therefore been assumed that the synthesis of satisfactory temperature-resistant fibres of a quality similar to those of natural asbestos will not be accomplished economically during the forecast period which we have in mind.

Looking ahead, it appears that one should concern himself as much with supply as with demand consideration. Had asbestos been readily available year in and year out since the late 1930's, it would probably be used even more widely today. Because the reserve position of existing mines is so strong

and because a number of additional discoveries have been made in recent years, future prices might be expected to remain relatively stable and availabilities to increase. Asbestos could, indeed, recapture some of the ground it has lost to other materials. Certainly it would be better able to move into new applications as and when the opportunity arose.

With respect to Canada's reserve position it is interesting to note that, over the past decade, something in excess of 250 million tons of new asbestos ore has been found. Less than one-third of that amount, meanwhile, was mined. The majority of properties have already proven up reserves sufficient to maintain their projected rates of output through 1980. Geographically speaking, the life of Canada's major producing districts can safely be visualized as extending beyond the year 2000. Since similar conditions are believed to apply in the other producing countries (and discoveries may well be made elsewhere), supply in the physical sense is unlikely to stand in the way of projection of past trends. Further improvements in mining and milling methods and even greater use of the lower-grade materials will also help to minimize cost. The choice of a 4% per annum increase as indicative of the probable long-run trend in world requirements does not appear to be unreasonable. We have therefore assumed that, over the next 25 years, the markets in which Canadian asbestos will participate will expand to between two and one-half and three times their present level.

(c) *The Future Pattern of Trade*

Of equal interest to Canadians is the share of the world market which will fall to producers in this country. Over the years it has varied. Usually, it has ranged between 60% and 70%. Excluding the U.S.S.R., it has historically run around 75%, though since 1945 it has shown a tendency to decline.

Increased competition is expected from countries behind the Iron Curtain. Already Russian asbestos is often offered at prices lower than Canadian and is sold for payment in local currencies under conditions of barter or within trade agreements negotiated between the governments concerned. At the expense of markets for Canadian long fibre, it has been freely exported to West Germany, France, Holland and Belgium. Although, traditionally, asbestos from this source has lacked care in treatment, present-day Russian fibre is well prepared for the market, of excellent quality and uniform in grade.

Southern Rhodesia, besides accepting payment in sterling instead of dollars, is also the world's chief source of low-iron chrysotile asbestos. This is the material preferred for electrical installation and similar defence purposes. These mines, like those in Russia, and the Union of South Africa can be expected to gain a larger share of the European market largely due to balance of payments considerations. Production has increased sharply in

recent years and in 1956 reached 120,000 tons, all in long fibre grades. Reserves are adequate for future development of the industry. Growth of a market for short fibre asbestos in the southern African subcontinent by nature of increased industrialization may be expected to result in a significant increase in production from this country. In world markets for asbestos, Canada may expect increasing competition from this source.

With respect to mineral discoveries 25 years is a long time. Worthwhile occurrences may be discovered in a number of places. While this applies to Canada's competitors, existing and potential, it also applies nearer home. Present indications are twofold, namely:

(i) that production could be stepped up substantially in existing Canadian mines without seriously hurting their proven position;

(ii) the possibility of bringing into production new mines in Canada between now and 1980 cannot be discounted.

In discussing ore reserves of asbestos it should be emphasized that variations in fibre potential can and do occur from deposit to deposit. There are two important considerations in designating asbestos bearing rock as ore:

(i) the percentage of asbestos in the rock which may be recovered in processing; and

(ii) the distribution of fibre length through the rock. Longer fibred asbestos grades are marketed at a much higher price than short fibre grades.

The Canadian asbestos mines now have proven reserves totalling some 600 million short tons. Another 400 million tons have been indicated but not thoroughly tested. It is estimated that when the present construction plan is completed the average depletion rate will be in the order of 20 million tons. Thus the industry has ahead of it as proven reserves the equivalent of 35 or more years of production; nearly 60 years if we include the ore which is still classified in the indicated category. In other words, if all exploration were halted now, this Canadian industry could continue to function and possibly even expand its productive capacity over the 20 to 30-year period which we have under review, providing that:

(i) future markets require the same distribution of fibre grades that are now marketed; and

(ii) the ore in reserve contains the proper distribution of long and short fibres.

In reviewing the ore discoveries which have been made during the past decade one is inclined to be somewhat optimistic. While 250 million tons of new reserves have been found, less than one-third of that amount has been consumed. Of this new ore, some 175 million tons have been found in the

oft-studied Quebec asbestos district. Though 75% is comparable in value to present operating ore bodies a sizable tonnage is suitable only for the production of the shorter fibre grades.

It is not illogical to assume that a comparable tonnage of new ore will be developed there over the next quarter century, hence extending the life of this district beyond the year 2000.

Other possibilities exist. The belt of ultrabasic rock in which the Eastern Township mines are situated extends from Vermont toward Gaspé. The largest United States mine is in the southernmost extremity. Although this area has been explored in detail by scientific means, there remains the possibility of a future discovery. Several kinds of rock favourable to deposition of asbestos occur in Newfoundland. Known deposits are being investigated there. Other belts of serpentine with asbestos occur in Chibougamau, near Noranda, and in northern Ontario. In these areas, so far, one mine has been developed at Matheson, Ontario. Other ore bodies have been indicated, some of which may prove to be of economic importance.

In Labrador and northern Quebec, small occurrences of crocidolite asbestos have been found and a search for larger deposits is now in progress. Travelling westward one notes extensive areas of ultrabasic rocks in that part of Ontario north and west of the Great Lakes, in northern Manitoba and in the northernmost parts of Saskatchewan. In all of these areas, there are also sporadic occurrences of chrysotile. Further search may result in one or more new mines there. Still farther west there is yet another belt of serpentine which crops out intermittently from southern British Columbia through to the Yukon. It is here, in the general vicinity of the Alaskan Panhandle, that Canada's latest producer has begun operations. In 1954 North American total dependence on Southern Rhodesia for low-iron chrysotile was broken by the commencement of mining operations designed to turn out a product of even better quality than that which had previously been obtained from overseas sources.

From the foregoing one thing stands out: namely, that, given time, supply is unlikely to be a major determinant of the volume of asbestos marketed throughout the world. Instead, costs of production, market connections and exchange considerations are likely to be dominant. Canada, under these circumstances, may be expected to retain the bulk of the North American market for this mineral. It could, meanwhile, lose ground in respect to the servicing of European and other non-dollar area demands. Tentatively it has therefore been assumed that Canadian mines will supply about 60% of the world's requirements in 1965 and 50% in 1980. Expressed in tonnage terms these assumptions would appear statistically as follows:

Table 32

CANADIAN ASBESTOS PRODUCTION

(volume in thousands of short tons)

Year	World demand	Canadian production	Canadian production as % of world total
1955	1,600	1,063	66
1965	2,250-2,500	1,350-1,500	60
1980	4,000-4,800	2,000-2,400	50

At present, some two-thirds of Canadian output is sold in the United States; 15% to 20% goes to the United Kingdom; 4% to South America; 2% to Australia, and the rest to a variety of African and Asian countries. Possibly the share taken by consumers in the Western Hemisphere will increase and those moving across the Atlantic and Pacific decline during the 20 to 30-year period under review. Transportation charges which tend to penalize the movement of the shorter and hence lower-grade varieties also tend to work in this direction. Canada's progressive concentration on North and South American markets may therefore be more apparent in quantity rather than in money value terms.

(d) *The Changing Structure of the Industry*

In some ways, Canada's asbestos industry resembles that of nickel. Each had its beginning well before the turn of the century. Each was a natural monopoly, at least for Canada. This country, then as now, possesses a major share of the world's known resources. For this reason, and because of the proximity of these mines to the world's largest industrial markets, they soon came to dominate international trade in these strategically important minerals.

Uniqueness and proximity to market had other effects as well. It soon attracted American and British capital. Companies whose headquarters and processing plants were located elsewhere soon gained control over most of Canada's producing mines. Their purpose from then on was to reduce their output to its most transportable form. Processing beyond the milling stage was consequently carried out at the market. Import tariffs and other types of international discrimination have worked in the same direction. Hence, only to the extent that more intensive recovery of lower-grade material has offered financial rewards have these foreign-owned corporations had a real incentive to expand their operations beyond the mining stage in this country. Most of the world's supply of raw asbestos is in strong hands. Furthermore the bulk of the production, including that from Canada, is sold by subsidiary to parent, most of the manufactured asbestos products being made in the country of control by companies which also own and operate the mines from which the asbestos comes.

The largest producer in the world, the Canadian Johns-Manville Co. Ltd., and several other important Canadian and African producers, such as

Turner and Newall Ltd., Bell Asbestos Mines, the Quebec Asbestos Corporation, the Nicolet Asbestos Company, Flintkote Company and Vermont Asbestos Mines, are all of the vertically integrated type. That is to say, they mine and mill the raw material, ship it to the principal market centres and there fabricate the finished asbestos product themselves. The asbestos from these so-called captive mines therefore constitutes raw material for company-owned manufacturing plants; and such surpluses as occur, together with such grades as cannot be used conveniently, are sold to other separate consumers. On occasion, these companies also purchase asbestos fibre from the other producers. Despite their size they do not always have available from their own operations the full range of qualities which they require. Still there are exceptions to the rule. The Canadian-owned Asbestos Corporation Limited and Johnson's Company Limited are producers only, having no asbestos manufacturing facilities within their own company orbits.

The largest operator anywhere in the world, the Canadian Johns-Manville Company, is a subsidiary of the Johns-Manville Corporation of New York City. The Quebec Asbestos Corporation Limited is a subsidiary of the Philip Carey Manufacturing Company of Cincinnati, Ohio; the Nicolet Asbestos Mines Limited of Nicolet Industries Inc., New York City; and Flintkote Mines Limited of the Flintkote Company, also of New York City.

British capital is also represented. The Bell Asbestos Mines, a large producer, is a subsidiary of Turner and Newall of Manchester, England;[106] the Asbestos Corporation Limited, the second largest producer in the Quebec area, and Johnson's Company, one of the pioneer corporations, are on the other hand reported to be financed by Canadian capital. Both producers and consumers are strongly represented in the ownership of the newly formed Cassiar Asbestos Corporation, now operating in British Columbia. Conwest Exploration of Toronto, Turner and Newall, and Raybestos-Manhattan all have important holdings in this operation.

In addition to those mentioned above, two other companies are actively developing new deposits with a view to commencing commercial operations within the next few years. These are Lake Asbestos of Quebec Limited, a subsidiary of American Smelting and Refining Company Limited, who are developing a property at Black Lake, Quebec, and National Asbestos Limited, a subsidiary of the National Gypsum Company of Buffalo, who are planning to bring a new mine into production at Robertsonville, Quebec. There is little, therefore, in the present development programme to suggest any substantial deviation from the long established pattern of ownership and control.

[106]Turner and Newall, together with the Cape Asbestos Company, control most of the asbestos production in Southern Rhodesia, the Union of South Africa and Swaziland. Like the American companies operating in Canada, Turner and Newall have extensive asbestos manufacturing plants of their own in the U.K. Thus the principal industrial markets are favoured by having first call on the world's principal sources of raw fibre.

As a result of these activities, the productive capacity of the Canadian mines will be increased considerably. Today there are 13 mills in operation —11 in Quebec and one each in Ontario and British Columbia. Their capacity is in the vicinity of 50,000 tons of asbestos rock daily.[107]

Construction planned or in progress will add materially to this figure. By 1958, Canadian capacity is expected to be in the vicinity of 60,000 tons. By that time the nation's producing potential may be approximately 1.2 million tons of fibre annually.

The use to which asbestos may be applied is governed primarily by fibre length. The longest fibres command the highest prices, and prices are progressively lower for the shorter grades. It is apparent, therefore, that primary attention must be given to milling processes that will separate the fibres from the parent rock and will fiberize them adequately with a minimum of breakage. Further efforts in this direction will undoubtedly result in more involved milling practices and a higher investment in initial processing plants in this country.

(e) *Prospects for Further Processing*

Since the 1930's a modest asbestos products manufacturing industry has grown up in this country. Absorbing about 4% of total Canadian mine output, its sales have been directed increasingly toward products like automotive brake linings, pipe, siding and paper used principally by the construction industry. Small amounts of the longer fibres are also made up into white textile asbestos goods including cloth, tape, rope, fillers, wicks and yarn. Meanwhile a goodly proportion of the highly manufactured asbestos goods are imported by the same companies that supply their parents with raw material in the United States and the United Kingdom. Only a very small proportion, less than 10%, of the Canadian manufactures are exported. Imports of such products exceed exports by a ratio of three or four to one.

Tariffs may be given as one of the reasons for the slow growth of asbestos manufacturing in this country. While the raw milled material enters the United States and many other countries duty free, heavy imposts are levied against the more highly manufactured products. Again, asbestos, and particularly the shorter fibres, is rarely the main component by weight of the products in which they are incorporated. Transportation considerations, therefore, tend to locate such industries as those producing asbestos-cement and asbestos-asphalt products in or close to their principal areas of consumption.[108] In the field of building materials, which constitutes an important segment of the market for asbestos, competition is severe in any case. Freight rate considerations—asbestos being light and other ingredients being

[107]More than 9% of the rock treated in these milling plants is marketed in recoverable form.

[108]Asbestos-cement products usually consist of about 80% Portland cement and about 20% asbestos-cement high pressure pipe. Much the same percentage is used in making roofing shingles, flat and corrugated siding and sewer pipe. Magnesia block and pipe insulation contain about 85% basic magnesium carbonate and about 15% asbestos.

much heavier—are often such as to cancel out this demand for asbestos were they required to move over much greater distances.

Under conditions of freer trade, Canada would presumably turn out manufactured products in which asbestos is the principal component. Also, to stand shipment over long distances they would consist principally of the long fibre applications. Thus it would seem that asbestos cloth, packings, safety clothing, electrical insulation, woven brake bands and heat insulation materials might well be produced close to the source. So might certain of the higher quality asbestos papers. On the other hand, asbestos building materials which necessarily contain a heavy weighting of cement, magnesia, asphalt, etc., would always go to manufacturing establishments close by the principal centres of construction. To give adequate strength to asbestos fabrics, cotton, rayon or other organic fibres are blended with it in various proportions. Imports of the latter would, therefore, be necessary. With this exception there seems to be no reason why a greater volume of textile products might not be made and exported from this country.

A further deterrent to more extensive Canadian processing is the capital investment which would be required to support an integrated and well diversified manufacturing industry in this country. Added to existing market uncertainties would be uncertainties as to duty, customs classification and possible quantitative import restrictions. Capital, under these circumstances, would be difficult to raise. Certainly it would face higher interest and other carrying charges. With this in mind it seems unreasonable to forecast any increase in the proportion of Canadian output retained in this country for further processing. Five per cent was assumed to remain here and be used essentially for domestic purposes.

While this is the general pattern, some further, though still elementary treatment, may become part of Canadian operations. In this connection it is interesting to note that two large new plants have recently been constructed in the United States for the specific purpose of reducing the iron content of asbestos produced in these companies' captive mines in eastern Canada. At least one of these plants (that erected by the Johns-Manville Corporation in Tilton, New Hampshire) was sited there because "it was within easy reach of the Canadian asbestos mines". Employing the shorter fibres, this operation is evidently designed to further the industry's waste utilization programme. Another method of beneficiation is under investigation by the United States Bureau of Mines. It consists of an attempt to elongate short fibres by various physical and chemical means. If either or both of these projects is successful, present indications are that processing of this type will continue to take place elsewhere than in Canada.

There is also a possibility, albeit for the distant future, of the recovery of certain valuable by-products at the mine. Both chrome and nickel minerals are known to be present in the ores mined in the Eastern Townships. Were

their prices to rise substantially or should processes be developed whereby they could be recovered from the tailings of these Quebec mines, they could add appreciably to the revenue derived from this industry. Neither of these possibilities nor that of fibre beneficiation on any scale in this country has been envisaged in the forecasts reported elsewhere in this study.

(f) *Price Considerations*

In its early years the price of asbestos fluctuated widely depending on conditions of supply and demand. More recently there has been a greater degree of stability. However, the general condition of scarcity, which has prevailed in most years since the end of World War II, has had a tendency to raise the price of asbestos relative to other minerals. When preparing value estimates our forecast has been for a further though more modest rise in price as expressed in real terms (i.e. 10% by 1965 and 25% by 1980).

Some doubt may actually be cast on whether Canada has been getting a true market price for its production. Asbestos fibres, particularly the longer ones, have in effect been rationed during the majority of years since 1935. Some people close to the industry believe that the Canadian mines could, under these circumstances, have obtained much higher prices than were actually charged to the parent companies and other consumers operating elsewhere. One reads in the Canadian Department of Trade and Commerce publication *Foreign Trade* dated July 4, 1953, "It is a credit to the industry and important for long-term outlook of the Canadian mines that they not only kept their price at reasonable levels but also did and still are doing an excellent job in the equitable distribution of available asbestos fibres." Certainly the industry viewed as a Canadian entity, has not been charging all that the market would bear. On the other hand, manufactured products containing asbestos have probably been sold at or near to competitive prices. The assumption, therefore, must be that the major beneficiaries of these pricing policies have been the parent corporations whose principal investment is in manufacturing facilities located elsewhere.

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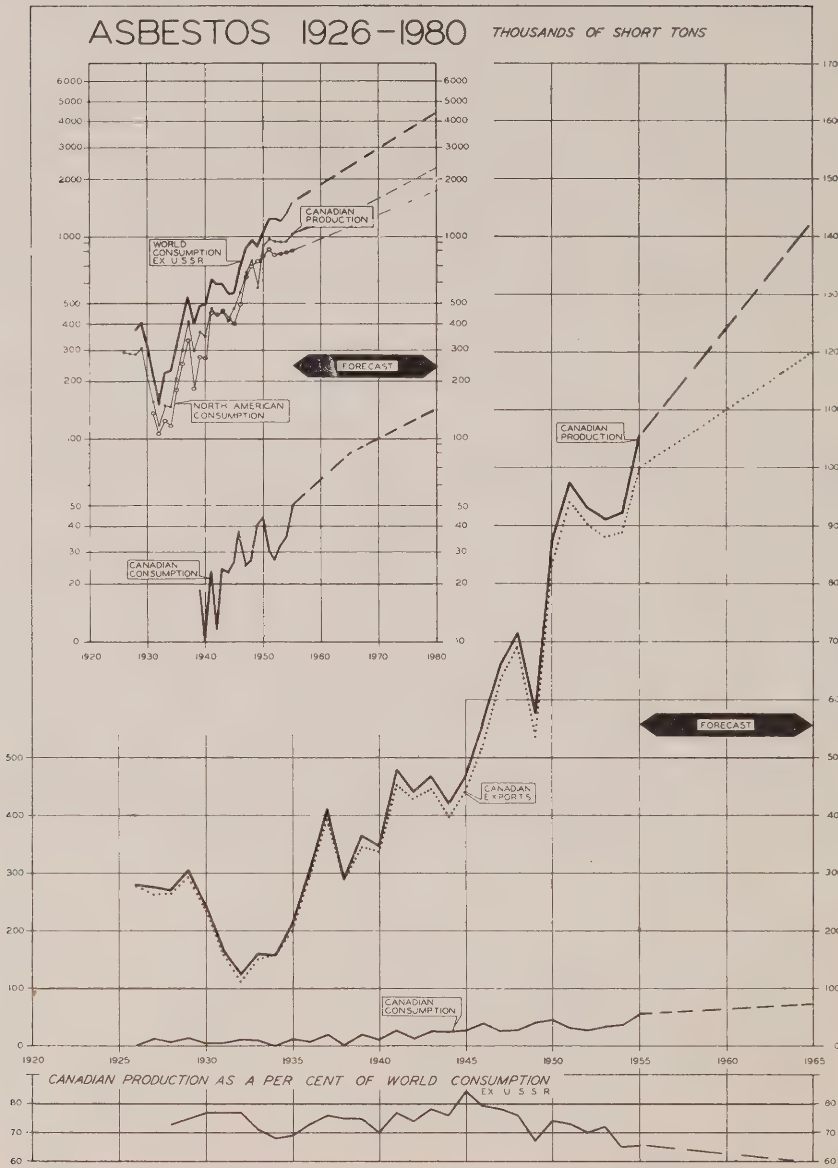
ASBESTOS 1926-1980
THOUSANDS OF SHORT TONS
WORLD CONSUMPTION EX U.S.S.R.
CANADIAN PRODUCTION
NORTH AMERICAN CONSUMPTION
FORECAST
CANADIAN CONSUMPTION
CANADIAN EXPORTS
CANADIAN PRODUCTION AS A PER CENT OF WORLD CONSUMPTION EX U.S.S.R.

P. Gypsum

Gypsum is well up on the list, both in volume and dollar value, of the mining industries of most countries. In Canada, it has an added significance. It is exported in substantial quantities as well. For this reason, it is second only to asbestos as the most important industrial mineral produced in this country.

At present valued at around $8 million and exceeding four million tons a year at the mine, activity both at the primary and secondary levels promises to go on increasing. This may be true relatively as well as absolutely. Experiencing a 6% per annum rate of growth since the mid-1920's,[109] the demand for gypsum is continuing to run well ahead of that of most other minerals. Invading some of the territory previously held by wood products in construction, and employed ever more extensively in industry, its position in Canada's export trade may also continue to improve both relatively and absolutely as the years go by.

Reference has already been made to the expanding market for gypsum. New uses have been developed. Others are being introduced. Meanwhile regional shortages, at least of low-cost material, are developing in the United States. These factors, together with the prospect of a decline in price relative to that of alternative materials, underlie much of the optimism with which this particular industry regards the future.

In recent years, gypsum products have found a growing market in construction, especially in house building. Nearly three times as much gypsum lath and wallboard are now used per housing unit as in the middle 1930's. This growth has been due partly to the relatively high prices and shortages of competitive products, partly to quality advantages, and, in no small measure, to their ease of installation. On these grounds alone, it is expected that the ratio of gypsum products to other construction materials used will continue to increase.

Cement is being used in ever-growing quantities. As a retarder in its manufacture, no other material compares with gypsum for combined economy and effectiveness. Recent studies have indicated that a considerably higher gypsum content would make concrete much more durable. If such is borne out in practice, it would result in an acceleration of the demand in this, the second largest use for gypsum.

Agricultural gypsum, used to offset alkaline soil condition and to correct for overdoses of ammonia-rich fertilizers, is being used in amounts whose growth bears comparison with the sales of fertilizer materials generally. Since the recently developed chemical soil conditioners are not expected to affect its market adversely, this appears to be another area for expansion in the 1960's and 1970's.

[109]The U.S. long-term rate of growth is more in the order of 4%.

Industrial applications are both numerous and varied. Calcined gypsum is used in the industrial plasters (terra cotta, pottery, molding statuary) and in the plate glass industry. Calcined gypsum is used as a filler in papers and paints. These markets can be expected to expand *pari passu* with the industries in which they are consumed. But beyond this, there are the added possibilities of the chemical industry. Gypsum and its near relation anhydrite are now being used commercially in Europe for the manufacture of sulphuric acid. Thus, a growing demand for sulphur, regionally, on this continent could provide yet another major outlet for this ubiquitous material.[110]

Geographically, the structure of the Canadian gypsum mining and processing industry is less likely to change. The quarries in Nova Scotia, which presently account for about 80% of Canadian output, will continue to ship most, if not all, of their production down the eastern seaboard of the United States. Meanwhile, smaller deposits in southern Ontario, Manitoba and British Columbia will look after the majority of Canada's internal needs. With the cost of mining being exceptionally low and rail freight charges high, the size of the local market will continue to be the main determinant of their output.

The same considerations apply to further processing. Because of substantial protection in the form of tariffs, the fortunes of the gypsum products manufacturing industries will continue to reflect the level of construction activity in the major areas in which their output is consumed.[111]

The structure of the export sector of the industry is not unlike that of others engaged primarily in supplying minerals to the United States. The two largest companies, the Canadian Gypsum Company (a wholly owned subsidiary of the United States Gypsum Company) and the National Gypsum Company (a wholly owned subsidiary of the National Gypsum Company of Buffalo) together account for some four-fifths of Canadian mine output. Most of this production is shipped raw to grinding, calcining and products manufacturing plants from New York down as far south as Florida and the Gulf coast ports. The remainder, whose preoccupation is mainly with the domestic market, include the Canadian owned firm, Gypsum, Lime and Alabastine Canada, Limited, one United States subsidiary and two subsidiaries of British companies.[112]

[110]The prospective costs of present gypsum and anhydrite using processes are still high compared with those dependent on North American sources of sulphur. Consequently, early commercial use of gypsum as a major source of sulphuric acid in the United States and Canada is considered unlikely.

[111]At the present time, eight companies are mining gypsum rock in 13 locations scattered across Canada. In 1954, there were 12 plaster mills and 10 wallboard plants in operation in this country. Total employment both in mining and manufacturing was of the order of 1,000 persons.

[112]The two mines in Ontario are operated by the Canadian Gypsum Company (U.S.) and Gypsum, Lime and Alabastine, Canada, Limited. In Manitoba, Western Gypsum Limited, a subsidiary of British Plasterboard (Holdings) Limited of London, England, operates alongside another plant owned by Gypsum, Lime and Alabastine, Canada, Limited. The latter company is also in production in British Columbia along with the Columbia Gypsum Company whose head office is in Vancouver, B.C.

Atlantic Gypsum Limited is owned and controlled by Bellrock Gypsum Industries of London, England. The plants at Humbermouth and the gypsum quarries at Flat Bay are owned by the Newfoundland government and operated by Bellrock Gypsum Industries (U.K.).

The possibilities of further processing are considerable. Evidence of this is the fact that value of mine production can be increased ten to fifteenfold in the manufacture of such construction materials as gypsum lath and board or its inclusion in such basic products as cement, soil conditioning agents and industrial plasters. Valued at anywhere from $1.50 to $2.00 at the mine, the price of comparable volumes of gypsum products such as wallboard, laths etc. may reach from $20 to $50 per ton. Obviously, the localities in which gypsum is mined (and in the case of exports, Canada as a nation) would benefit considerably from the further manufacture of raw gypsum. Carried through its various stages from grinding and calcining to its incorporation along with other materials into semi-finished products, the full sequence from mine to the more generally marketed commodities is not infrequently carried out near the resource rather than in the principal areas of final demand.

Evidence of this is contained in a recent analysis of location published by the United States Bureau of Mines ("Gypsum", a chapter from *Mineral Facts and Problems,* United States Bureau of Mines, Bulletin 556, 1956). It states: "Transportation factors loom large in the economics of the gypsum industry. Because both raw gypsum and most gypsum products are relatively heavy for their value, the plant should be as near as possible to the mine and also to the main consuming area. This ideal condition has been thoroughly tested by some plants whereas others, especially in the Western States and on the East Coast, have found it necessary to ship either the crude rock, the finished product, or both, for considerable distances.

"One large operator in the West found it most practical to build a plant and company town near the mine and ship the finished material a few hundred miles to its principal market area. Another mines a deposit adjacent to an ocean port in Mexico and ships the crude in a company-owned freighter over 1,000 miles to three processing plants in important market areas. Noteworthy from a point of comparison is the fact that, in Southern California, both of these companies sell on the same market."

At present, the bulk of raw gypsum requirements of plants located along the Atlantic seaboard of the United States is supplied from quarries in Nova Scotia (although some crude from Jamaica and the Dominican Republic has been used experimentally). Further manufacture at, or close to, the mine would thus be possible were it not for the United States tariff. As in numerous other instances it is designed to let in the raw material and to keep out the manufactured product. The following imposts are levied against Canadian gypsum and its products:

(a) gypsum—crude, lump	free
(b) gypsum—ground or calcined	50¢ a ton
(c) gypsum—wallboard and lath	17.5% ad valorem

Needless to say, these duties have accomplished their objective. As long as they continue in force, they are likely to prevent the establishment of an

export industry in Canada which engages in anything more than the export of the run-of-mine material.

Given the present obstacles to trade the great bulk of the mine production in the Maritimes will continue to go to the United States. Now accounting for nearly one-third of United States raw gypsum consumption, their contribution in this regard may grow rather than decline. Elsewhere in Canada, when construction is booming, certain gypsum products will be imported. This may continue to be true of southern Quebec, southern Ontario and British Columbia. However, taking one year with the next, Canadian mine production west of Nova Scotia is likely to move upward and somewhat ahead of the general level of construction activity in this country.

As for ownership and control, these are as in many other Canadian mining industries principally in foreign hands. At least 80% of the Canadian output of raw gypsum is produced by companies whose shareholders reside in the United States. Despite the domestic orientation of the products manufacturing plants, these, too, are in large part foreign owned and controlled. Of their total value of output in 1954, about half originated in facilities whose processes, management and general selling policies were patterned after those of their parent companies in the United States. British interests are also active in this connection.

Financing of expansion both at the mine and in the processing stages has resulted almost entirely from the reinvestment of earnings from export and domestic sales. While the stocks of the parent companies are generally available on the open market, in very few cases can Canadians participate directly in the fortunes of the subsidiary Canadian operations.

Note

The average value of Canadian gypsum at the mine in 1954 was $1.80 a ton. This reflects, essentially, the efficiency with which this mineral material can be broken up and hauled away mechanically.

The following statistics point up the fact that the price of the Canadian product as exported is substantially below the price of gypsum at the mine in the United States. The value per ton of Canadian gypsum entering the United States in 1953 was approximately $1.38. At the mine in the United States, it was about $2.80, or double the Canadian figure.

Q. Salt

Salt is abundant, widespread in occurrence, and easily produced. It occurs, is recovered and finally used in both solid and brine form. Canadian reserves, meanwhile, are enormous. Yet, because these resources are distinctly regional as to location and because salt cannot economically be trans-

ported over long distances, this country will continue to import a small though significant proportion of her own rapidly growing needs.

With an output already in excess of one million tons annually, salt mining in this country is subject to many influences; some are old, some new. Consumption, besides growing steadily in such old established uses such as food seasoning and preserving, agriculture, water treatment and dust and ice control, is also in considerable demand in the chemical industry. Now the largest single use of salt in this country, the manufacture of chlorine and sodium chemicals will no doubt continue to provide the main dynamic for the future.[113] Other significant developments, not the least of which is a continuing decline in cost relative to other goods and services, will help to maintain the salt industry's long-term rate of growth. Ranging around 5% per annum since 1920, it could result in a tripling of the industry's volume of output between now and 1980.

Technological improvements in mining and processing are having much to do with the course demand has taken. Bulk mining methods, whether they involve the recovery of salt in solid form or in solution, have been revolutionized since the 1930's. The removal of impurities, the inclusion of chemical additives and new processes for evaporation and recrystallization have accompanied the introduction of similar techniques in the chemical industry. These are among the reasons why labour productivity in this industry is showing a persistent rise, and why the price of salt, relative to other things, has declined steadily over the years.

The geographical structure of the Canadian industry continues to reflect the availability locally, of this costly-to-transport resource. Huge underground beds, several hundred feet in thickness, underlie much of southwestern Ontario at depths between 800 and 1,500 feet. This together with the large nearby markets in many of Canada's secondary manufacturing industries, is the principal reason why three-quarters of the nation's output comes from mines in the vicinity of Windsor and Goderich.

Tariffs charged on salt tend to prevent its movement either way across the international boundary.[114] This is why the Canadian salt industry is expected to look after a large part, if not all, of the growing requirements of Ontario and southern Quebec. The United States duty also tends to prevent exports southward into the salt mining states of Michigan, Ohio, New York and Pennsylvania from reaching major proportions.

While deposits occur in all four of the Atlantic provinces, production so far has been confined to Nova Scotia. Several mines are either being

[113]Chemicals production consumes about half of all the salt mined in Canada. In the U.S., where the chemical industry is more heavily intrenched, it takes about 75%.

[114]The U.S. tariff against Canadian exports, which has been in effect since the Geneva Conference of 1948, amounts to 40¢ per ton on bulk salt, and 70¢ per bag of packaged salt. Since bulk salt at the mines has a value in the vicinity of 50¢ per ton, such a levy acts as a considerable deterrent to trade. The Canadian tariff is even higher; it ranges between 60¢ and $1 per ton on the types of coarse salt which are generally brought into this country. Salt for the fisheries, by contrast, enters duty free.

worked or prepared for underground mining. Tapping beds 1,000 feet or more in thickness and under lesser cover than is the rule in southern Ontario, they now account for about 15% of the total Canadian output. Regionally, their market extends throughout the Maritimes and into Quebec. With the completion of the current expansion programme, it is expected that these workings will not only displace some of the imports moving into the area but, also make substantial tonnages available for export into the northeastern United States.

Salt deposits of great areal extent, underlie much of the Canadian Prairies. Available at depths running from 500 to several thousand feet, they are now being mined to a limited extent in southern Manitoba and central Saskatchewan, and recently in increasing volume in north central Alberta. As in southern Ontario, the growing needs of the chemical and chemical process industries have provided most of the incentive for expansion.

British Columbia, meanwhile, possesses no known deposits of salt or brine of economic importance. Therefore, to an even greater extent than is common in the Maritimes and Newfoundland, it is dependent on United States sources of supply for its fishing industry, road and railway maintenance and industrial requirements. Even greater resort will have to be had to Albertan and Californian deposits as the production of industrial chemicals gets under way on Canada's west coast.

To sum up, it appears that, during the forecast period under review, consumption of salt in Canada will continue to rise at a rate well above, and, at times, double, that of the nation's output of other goods and services. Domestic production, because of tariff protection and the regional displacement of imports, may rise even more rapidly. Exports, though small, could become significant. This is not to say that there will be a commensurate increase in employment and investment opportunities. Further improvements in mining, hauling, solution extraction and brine processing techniques, will limit the impact on the rest of the Canadian economy of this already highly mechanized industry.

R. Sulphur

(a) *General Introduction*

Sulphur is one of the principal raw materials of the chemical industry. Like salt and limestone, it is employed in a host of chemical processes, the numbers of which yearly grow more prodigious. So extensively is it used in the form of sulphuric acid that consumption of the latter is sometimes regarded as a handy indicator of economic change. Suffice it to say that sulphur permeates the industrial fabric so thoroughly that an adequate supply at reasonable price is essential for orderly economic development.

Fortunately sulphur can be won from many sources. Among these are salt domes, pyrites, other metallic sulphide ores, natural gas, crude oil and coal. So abundant is it, in fact, that no shortage in the absolute sense need ever occur. Yet, so dependent has much of the world become upon the native sulphur produced by the hot water melting (Frasch) process that possible limitations from this source, coupled with unforeseen increases in demand, have threatened to bring about a major dislocation in the world market for this important chemical raw material.

At present most non-Frasch sulphur sources are more or less marginal. They must enjoy some local advantage in order to compete with the major product recovered from the cap rock of salt domes characteristically found in the Gulf coast area of the United States. Traded in limited quantities when the latter is in good supply, they have nonetheless been called upon to meet a growing proportion of the world's over-all sulphur requirements.

Canada, unlike the United States and Mexico, does not possess large commercial reserves of native sulphur. On the other hand, vast quantities are mined in chemically combined form along with iron and other metals. Treated locally or exported on occasion, the latter consist principally of pyrite or pyrrhotite. Additional tonnages of sulphur are also becoming available as a result of the need to process natural gas prior to its introduction into pipelines for long distance transmission. Sour gases must be treated in this way. So must crude oil with an appreciable sulphur content. Numerous plants are being set up, both in western Canada and at the principal oil refining centres, with this end in view.

Stimulated by these developments and encouraged by the possibility of recurring native sulphur shortages, Canadian production has now reached the point where it is capable of meeting more than half of the nation's total sulphur requirements. Further increases in output are also in prospect. As a result, exports may exceed imports soon after 1960. Thereafter, and depending upon the success attendant to the search for additional native sulphur deposits elsewhere, this country may become increasingly a net exporter of this large-volume, low-priced element.[115]

(b) *Background of the Industry*

Sulphur may be recovered in the form of elemental sulphur, sulphuric acid or sulphur dioxide from pyrites and hydrogen sulphide (sour natural gas). To further complicate matters, sulphur or its compounds may also be extracted from many industrial wastes including steel mill pickle liquor, oil refinery waste, smelter gases and other plant effluents.

[115]Sulphur is at present sold for less than a cent a pound. No other chemical of better than 99.5% purity is available at a comparable price.

Despite these various possibilities, the bulk of the world's supply is at present obtained from native sulphur deposits, and iron pyrites. Historically, the leadership has seesawed back and forth between the two. For a while Sicilian native sulphur, mined by conventional underground methods and beneficiated at the surface, dominated the market. Gradually, however, its price increased. This encouraged consumers to look to countries like Spain where pyrites could be mined relatively cheaply. This was the position in Western Europe toward the end of the 19th century.

Then, around 1900, Herman Frasch advanced the idea of pumping hot water into the sulphur deposits known to exist at the crest of several extensive salt domes in Texas. Thrust downward under pressure, hot water proved capable of melting this material and bringing it to the surface where, upon cooling, the sulphur solidified. The product—the so-called crude sulphur of commerce—was found to have many advantages. Being in elemental form, its shipping costs were low. Due to its 99.5% purity, it could be converted into sulphuric acid in plants which were simple compared to those needed to treat pyrites. Even more important was the fact that its initial cost of production was well below that involved in the hand mining of the combined sulphur ores. Possessing these advantages, the native product became, over the years, the preferred raw material not only in North America but also, since 1945, in Western Europe as well.

It is noteworthy that, even in the United States, other sources have begun to attract attention. In general, they have made headway in areas where sulphur tends to be a waste product of other mining and mineral treating operations. Bearing only a small proportion of total cost, sulphur produced in this way often has local compensatory advantages. Thus, chemical process industries near the gas fields or not too far distant from North America's principal non-ferrous metal smelters and refineries may be more economically served from such by-product sources as those being established in central and western Canada.

During the past half century, the world's sulphur requirements have risen in spectacular fashion. So persistently has demand increased that, around 1950, requirements finally caught up with and passed the immediately available capacity of the Frasch mines in the United States. Large inventories that had been accumulated in previous years by then had been exhausted and, with the outbreak of war in Korea, a serious shortage ensued. Priorities, taking the form of industry and country allocations, were set up by the United States National Production Authority. Doubtful as to whether the native sources of supply could be counted upon to meet most of their future requirements, users in Canada and Western Europe were, for a time, encouraged to obtain some portion of their over-all needs from sources closer to home.

Proven processes were revived and new ones developed. A variety of sulphur extraction plants were built, the majority of which are in operation at present. Particularly important was the creation of new facilities for the recovering of sulphur from metal smelter effluent gases and from pyrites, which had previously been rejected along with rock and other submarginal material at the mines themselves. Relief also came from the processing of natural gas. Production of this unique fuel was already increasing by leaps and bounds. Now, as a result of the cleanup procedures needed to treat sour natural gas, this source supplies over 5% of North America's over-all sulphur needs.

One must not lose sight, however, of the recovery effected by the native sulphur producers. In recent years, several new salt domes have been opened up in the United States. Production also commenced in Mexico in 1953. In total, output from these sources has been increased by some 1.5 million tons or about 30% since 1950.[116] World capacity at the present time is in the order of 15 million short tons.

(c) *Long-Term Consumption Trends*

Any attempt to present a clear and well-rounded statistical picture of the world's changing sulphur requirements is hindered by lack of comparable data. Not only are the sources of sulphur numerous but much of it is consumed in other than elemental form. By-product sulphur, because it is often used directly in the production of chemicals and chemical-type products, is rarely measured in commercial terms. Average yields, therefore, have to be assumed. And with most other minerals, consumption information is also incomplete. Rarely does it extend back over a period of years. Long-term trend data adequate for our purpose are therefore lacking.

Figures prepared a few years ago by the International Materials Conference were therefore employed as a guide to future events. These indicate that world consumption has approximately trebled over the past 30 years. The demand for sulphur has, in other words, been rising at an average long-run rate of approximately 4% per annum. Statistics published by the United States Bureau of Mines indicate that apparent consumption in that country has been increasing in comparable fashion since 1930. Such data as are available for Canada and Western Europe suggest that, if anything, consumption has tended to accelerate in recent years. If this is so, a 4% trend line may be taken as a conservative projection of future world requirements 10 and 25 years ahead.

For forecasting purposes a breakdown by application is of interest. Approximately 75% of all sulphur is consumed eventually as sulphuric acid. This is a well established outlet. The nearest acid substitute, hydrochloric

[116]Salt domes on this continent are presently supplying around 80% of all the sulphur consumed in North America and account for nearly 50% of the world's output of this strategically important material.

acid, is about four times as costly to manufacture. Hence, the majority of chemical-type operations in which acids are required will continue to draw on sulphur and sulphur-bearing compounds.

Tracing sulphur consumption on through to its finished product, we find that approximately one-third turns up as fertilizer of one kind or another. The chemical industry absorbs a similar amount. Chemical process industries which also employ substantial tonnages of sulphur include the manufacture of synthetic textiles, the production of primary iron and steel, oil refining, pulp and paper mills, and plants producing such unlike commodities as paint and synthetic rubber. The majority of these applications are expanding at rates well above that of industry in general. Only a few, like iron and steel, are moving upward in line with or somewhat behind North American and world averages.

Some further light may be cast upon future requirements by examining the outlook statement prepared for individual industries. Fertilizer consumption as forecast elsewhere in the Commission's studies is rising at better than a 5% per year rate. Chemical output may increase at about 6% per annum. Petroleum refining, pulp and paper production and the manufacture of synthetic textiles may follow a 4% compound growth curve. Iron and steel's annual increase, meanwhile, may be more like 3% a year. Hence, a 5% annual increment may best represent the future course of demand. For purposes of this analysis, world requirements of North American sulphur have therefore been assumed to rise to between three and four times their present level by 1980.

(d) *Long-Term Price Trends*

Compared with the general wholesale price level, the price of sulphur has shown a long-run tendency to decline (see chart entitled Price Trends, Current and Deflated, U.S. Annual Averages, 1900-55 in Chapter 5). This downward movement in real terms was arrested in 1950 when a world shortage aggravated by the Korean conflict caused a sharp reversal to take place. The United States' price skipped upward from $16 to more than $25 a long ton. Government regulations were introduced. Nonetheless quotations from overseas sources at one time reached as high as $200 a long ton. More recently, as new mines have been brought in and Frasch sulphur production expanded, prices have become stabilized at a level comparable in real terms to those in effect in 1945.

At present, elemental sulphur produced as a by-product from natural gas cleaning plants is commonly sold at prices comparable to those obtained for Frasch sulphur. Pyrites prices, meanwhile, vary widely, ranging anywhere from $2 to around $8 a long ton. These latter figures are influenced by intra-company accounting procedures (which sometimes tend to obscure its true

economic worth) and the high transportation cost penalties which must be overcome by native sulphur producers attempting to compete in geographically sheltered markets of this kind.

(e) *Canadian Demand and Production Prospects*

For many years Canadian industry imported the bulk of its sulphur requirements. Elemental sulphur imported from the United States supplied practically all of the needs of the pulp and paper mills and chemical plants located in eastern Canada. Only in respect to the manufacture of fertilizers at Trail were pyrites used extensively in the production of sulphuric acid.

The threat of a worldwide shortage in 1950 changed all that. Numerous projects were investigated and within a few years half a dozen plants had been built to meet the needs of large consumers, the majority of which were located at a distance from the world's principal shipping lanes. First to come into production was a liquid sulphur-dioxide plant at Copper Cliff, Ontario. It utilizes waste smelter gases. Subsequently pyrites recovery operations made substantial tonnages of sulphur and sulphur bearing materials available to Canadian consumers. Roasting facilities built by the mining companies or, as in the case of several pulp and paper mills, by the user industries themselves, helped to overcome what might otherwise have been a serious sulphur deficiency in this country.

Production has risen rapidly. From approximately 230,000 tons in 1948, it exceeded 600,000 tons in 1955. Meanwhile exports have increased and imports declined. Sales of pyrites, principally to the United States rose from a 1948 figure of 50,000 tons to around 200,000 tons seven years later. Imports, which in the postwar period had run as high as 400,000 tons, have since fallen to around the 350,000 ton mark.

Currently, Canadian consumption is in the vicinity of 650,000 long tons. Over half of this sulphur is consumed by the pulp and paper industry. Another 30% is used in the manufacture of fertilizers. Five percent is used in the production of chemicals and another 1% is incorporated into petroleum products. This pattern is in decided contrast to that prevalent in the United States. There, chemicals manufacture absorbs about 25% of the total, fertilizers about 30%, petroleum refining around 10% and pulp and paper manufacture only 5%.

The demand outlook for Canada is, on this account, heavily weighted by the prospective development in the pulp and paper industry. Newsprint requirements may about double over the next 25 years. (See John Davis *et al, The Outlook for the Canadian Forest Industries,* Ottawa, 1957.) Fertilizer production, meanwhile, may grow at around 5% a year. Chemical requirements may mount at about a 6% per annum rate. Other uses, though

they could grow even more rapidly, may continue to be modest in amount during the years between now and 1980.

In all, a total requirement of 1.5 million tons of elemental and contained sulphur is envisaged for 1980. Though considerable, it falls short of the domestic productive capacity likely to be available at that time. Ten years from now as much as 11.0 million tons may be available annually from the western gas fields. A comparable amount may be forthcoming from pyrites mines and the nation's non-ferrous metal smelters and refineries.

Marketing problems are therefore in prospect. Consumers in eastern Canada will probably continue to import a goodly proportion of their requirements from Texas, Louisiana and Mexico. Meanwhile, long rail hauls involving comparatively high unit costs will limit the acceptance of sulphur produced west of the Great Lakes.

Looking 25 years ahead, the position appears to be one of surplus capacity. Capable of producing between two and three million long tons of sulphur a year, the industry may have to store some part of its output above ground. (This may be true particularly of sour gas production.) The remainder over and above that which cannot be sold conveniently to local industry will have to be exported at comparatively low prices to markets up and down the west coast, in the central United States and Western Europe.

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S. Potash

(a) *General Introduction*

Potash is one of three essential fertilizer ingredients. Usually required in fixed proportions along with nitrogen and phosphorus, the demand for potash minerals has been rising rapidly in recent years (see also John Davis, *The Canadian Chemical Industry,* Ottawa, 1957). Since late 1946 con-

sumption has doubled. The outlook, assuming a growing awareness on the part of farmers of the labour saving and other economies stemming from the more extensive use of fertilizers, is equally encouraging. Since substantial resources have recently been discovered in this country, Canada may therefore become an important producer of this particular mineral.

Potash is commercially available from comparatively few countries. Half a dozen sources presently meet the bulk of the world's requirements. These are located in Germany, France, the Middle East, U.S.S.R. and the United States. Political factors, meanwhile, have been responsible for a dividing up of the world's principal agricultural and chemical markets. Two world wars interspersed by an intensive government sponsored development programme in the United States have, in other words, fostered hemispheric self-suffiency. Currently, United States mines supply about 90% of North America's over-all needs. Regionally, and this applies with some force to eastern Canada, there is still a trans-Atlantic trade in this low unit cost, large-volume material.

Against this background, the discovery of extensive potash beds in southern Saskatchewan attains added significance. Underlying much of the central and southern plains region of the province, they consist of a reserve which, in total, may run into thousands of millions of tons. If this material can also be mined commercially, (and there is a considerable body of opinion both in industry and in government circles which holds that this is so), Canada may be found to possess by far the world's largest single exploitable resource. Sizable markets are meanwhile developing within a convenient radius of the projected south Saskatchewan mines. Assuming that mining costs in Canada are not too far above those presently being encountered in the United States, potash might therefore reach the point where it would assume second place behind asbestos as the most important industrial mineral being mined and exported from this country.

(b) *Background of the Industry*

Prior to World War I, potash was produced chiefly in Germany by a German government controlled cartel. In 1919, an international syndicate was formed and the world market was divided between Germany and France, (the latter having gained temporary control over many former German mines). Subsequently, other producers in Palestine, Poland, Russia and Spain became participating members of the giant monopoly. Because of this, and because of the interruption to potash shipments caused by the Allied blockade of Germany during the 1914-18 war, the development of a domestic potash mining industry received considerable political support in the United States. With government assistance, potash salts, along with certain other agricultural and industrial chemicals, began to be recovered from the crystalline salt mass of Searles Lake in California. However, it was the search

for oil which eventually turned up the necessary resources. Significant traces of potash were found in drill cores recovered from exploratory wells in New Mexico in 1925. Further exploration carried out by the United States federal government and other agencies revealed the presence, at a depth of about 1,000 feet, of a bedded deposit of sylvinite of a quality comparable to the better deposits then being worked in Germany. Ample reserves, with a bed thickness permitting economic recovery using conventional mining methods, took time to prove up. Though production first began in 1931, the United States did not become self-sufficient in potash until World War II again interrupted the flow of imports from Western Europe.

As a result of further discoveries and a considerable improvement in large-scale underground mining methods, these two areas (Carlsbad, New Mexico, and the Searles Lake salt bed) now supply all but a fraction of total United States requirements. In 1955, that country's output totalled 2.1 million short tons. Imports amounted to only about 100,000 short tons. Some United States produced potash was, meanwhile, being exported to Canada and South America.

Important successes have also been reported elsewhere. Since the end of World War II, substantial deposits have been discovered in the United Kingdom. Resources running into hundreds of millions of tons have been proven up in Yorkshire. Production is being expanded in Israel. Many other occurrences are also being investigated. Besides the countries already mentioned, smaller and relatively lower-grade deposits are attracting interests in Australia, Chile, China, Eritrea, Ethiopia, India, Italy, Japan and Korea.

Interest in this report naturally centres on recent Canadian developments. As in the United States, the occurrence of potash at depths first became known as a result of the search for oil. Indications that the beds underlie a very substantial part of central and southern Saskatchewan were first reported in 1943. Since then, drill cores have revealed beds up to dozens of feet in thickness and extending from the Unity-Biggar area (south of North Battleford) on the northwest, eastward at least to the Manitoba boundary and southward possibly into the Williston Basin region of North Dakota and Montana.[117] Though the average depth of these Canadian occurrences is several times that being worked in the United States and their quality varies considerably from one place to another, they are of commercial interest because of their tremendous extent and their location relative to a number of North America's largest and most rapidly growing markets for fertilizer material.

Suffice it to say that possibilities in the south-central plains area have been such as to attract the attention of most of the producing companies in

[117]The Canadian potash occurrences may extend well into the United States. However, if such are found in North Dakota and Montana they will, due to the southward slope of the geological structure in the central plains area, be found at even greater depths. Seven thousand feet below the surface has been mentioned as a likely horizon for their occurrence. Except that solution methods be developed for their recovery, mining is unlikely to be economic under such circumstances.

the United States. The Potash Corporation of America, for example, has completed ground freezing operations, made good progress in sinking a shaft, and let an engineering construction contract for surface plant facilities. Others which have already commenced drilling or hold exploration permits issued by the Saskatchewan government are the Duval Sulphur and Potash Co., the Southwest Potash Corp. (a subsidiary of American Metal Co. Ltd.), International Minerals and Chemicals Corporation and the United States Borax & Chemical Corporation. Canadian participation, so far, is modest by comparison.

(c) *Reserve and Cost Considerations*

The world's established reserves of high-grade soluble potash salts (principally potassium chloride) are very large. Those known to exist in Germany, France, the Middle East and the United States are in the order of 40 billion tons of contained K_2O. Assuming satisfactory methods are developed for their production, the addition of the Canadian resources could double this amount. By contrast, world production is only in the order of three million short tons. Thus the world's economically producible reserves can be measured in thousands, if not tens of thousands, of years of supply.

The United States' position differs only by degree. Though less than 1% of the world's economically recoverable reserves has as yet been proven up there, resources sufficient to support that country's present level of output for at least another half century appear to be in sight. It is geographical rather than quantitative considerations which tend to limit their area of usefulness. Potash, being a bulky, low unit value commodity, is relatively expensive to transport. It is at a disadvantage when attempting to compete in distant markets with reasonably low-cost local sources of supply. No doubt New Mexico and California will continue to meet all, or practically all, the potash needs of the southern and eastern states. Due to their proximity, the Canadian mines may meanwhile be developed to meet the growth requirements of the Pacific northwest and certain of the middle eastern states.

Conclusive information as to relative mining costs was not available at time of writing. Most of the Canadian potash occurs at depths ranging between 2,500 and 5,000 feet. Some difficulty has been encountered in sinking shafts through relatively soft overburden and rock. Costly freezing methods have had to be introduced prior to the cementing of their walls. Mining machinery, having to be imported, also tends to be somewhat more expensive than is the rule in the United States mines. Offsetting influences include the need for United States mine operators to treat progressively lower-grade material and to work generally thinner seams than may be exposed by operations in Saskatchewan.

Though coal mining methods and equipment have generally proved suitable on this continent, solution mining holds out intriguing possibilities. Attempts have already been made in the United States, England and Canada to recover potash by flushing out the beds with hot water. Though these experiments have been inconclusive, such an approach, if eventually found to have commercial worth, would have considerable advantage so far as Canadian potash is concerned. By helping to narrow the production cost differential, it would extend the North American market area which could efficiently be served by Canadian sources of supply.

(d) *Long-Term Consumption Trends and Market Prospects*

Since 1930, world consumption has approximately trebled. Global demands, in other words, have exhibited a long-run rate of growth of between 4% and 5% a year. More recently, as the economics of fertilizers use has gained greater recognition, there has been a tendency for consumption to accelerate. On this continent a 10% annual rate of increase in demand is more descriptive of the opportunities which have arisen during the post-World War II period.

Better than 90% of the total is employed along with fixed nitrogen and phosphate chemicals for purposes of fertilization and otherwise improving the condition of the soil. Usage in other applications is only exhibiting a slow relative gain. Thus, it is to mixed fertilizer production that one must turn when assessing over-all sales prospects. The long-run upward trend in agricultural usage suggests that North American consumption might rise from approximately 2.5 million short tons (K_2O content) to around 7.5 million tons in 1980. Figures prepared by various food experts concerned with nutritional standards suggest that as much as ten million tons may be required in the United States and Canada a quarter of a century from now. A third approach takes into account the need to maintain the fertility of the soil. It has been estimated that about five million tons of potash is removed annually by cropping from agricultural lands on this continent. This amount must be replaced if the latter's productivity is to be maintained. Further quantities are lost through natural leaching and erosion. Hence, a minimum of eight million tons, and possibly as much as ten million tons, of potash must be supplied if Canadians and Americans are to counteract such annual losses as are in prospect 25 years hence.

Chemical requirements are still relatively small. Less than 8% of all the potash mined or imported into the United States and Canada in 1955 was employed by the chemical industry. Though new industrial chemical uses for potassium compounds may be developed, it is expected that the tonnages used in the manufacture of new type explosives and propellents may continue to be of modest proportions. For this reason, the development of new chem-

ical uses has not been assumed to alter substantially either the amount or regional characteristics of the North American market for this mineral during our forecast period.

Assuming that North American sales are in the order of eight million tons a year in 1980, there is still the question of the share supplied by Canadian mines. Properties are being readied in this country which are capable of sustaining a yearly output of around one million tons. This figure could be reached in the early 1960's. Thereafter, the proportion of the total North American market captured by Canada will be determined by changing agricultural practices on the one hand, and by relative mining costs in Canada and the United States on the other. Twenty-five percent to 30% of the total has been mentioned as the likely contribution of the Saskatchewan deposits were costs there to be reasonably in line with those encountered in New Mexico. Should this come to pass, Canada's mines might produce around 2.5 million short tons of potash in 1980. At an average price of $20 a ton the industry's gross value of production might range anywhere from $40 million to $50 million.

(e) *Prospects for Further Processing in Canada*

Potash salts can be separated from other minerals either by flotation or fractional crystallization. This step, aimed at producing a reasonably pure product, will undoubtedly be taken at or close to the mines themselves. By-products such as common salt and sodium sulphate will therefore be available locally for use by chemical process industries. Whether or not advantage will be taken of these offerings by firms producing potassium chemicals is, however, problematical.

The manufacture of complete fertilizers presumes the availability, also, of nitrogen and phosphate rock. The former can be produced from natural gas or oil. The latter would have to be imported by rail from the United States. On this latter account, and because ammonia production based on natural gas is now tending to be concentrated in the main fertilizer using areas of the continent, it is thought that such mixed fertilizers as are produced close by the potash mines in Saskatchewan will be sold primarily in western Canada.

Export prospects for other than fertilizer grade potash are also limited. The main deterrent in this case is the United States' tariff which discriminates against potassium chemicals of appreciably higher unit value. This ranges from 0.75¢ a pound on potassium carbonate and potash alum to 25¢ a pound for potassium iodide. Other potassium chemicals, not separately classified, generally are up against a rate of 12.5% ad valorem. By contrast, all crude fertilizer material continues to enter that country duty-free.

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T. Other Industrial Minerals

(a) *Fluorspar (Calcium Fluoride)*

Due to the expected growth in the market for aluminum, steel, ceramics and fluorine chemicals, Canadian fluorspar production may rise substantially over the next quarter century. Domestic reserves, chiefly in Newfoundland, are extensive. They can be mined cheaply and are close to low-cost water transportation. Assuming that producers in this country will also continue to obtain relatively free access to the United States markets, it seems likely that they will be able to expand their operations considerably between now and 1980.

Fluorspar has been found at several localities in Newfoundland, but the principal commercial deposits are in the vicinity of St. Lawrence, a town on the south coast of the island. Most of the veins in which it occurs are within six miles of tidewater. These are being mined at comparatively shallow depths.

The presence of fluorspar in the St. Lawrence district has been known since 1839. However, aside from the early prospecting of some of the fluorite veins for the lead content, the area remained dormant until 1933 when the St. Lawrence Corporation of Newfoundland Limited began surface mining for shipment to the Dominion Steel and Coal Corporation Limited at Sydney, Nova Scotia. Newfoundland Fluorspar Limited (a subsidiary of the Aluminum Company of Canada), or rather its predecessor American-Newfoundland Fluorspar Company, entered the field in 1936 and began to make shipments in the spring of 1942. Progress has been such that the district now ranks as the most important fluorspar producing centre in the Commonwealth and second or third largest in the world. One of the mines has the distinction of being the world's largest single producer of this strategically important metal.[118]

"Both of the companies produce a partially concentrated spar, by means of heavy media separation, which must be further beneficiated by flotation. The St. Lawrence Corporation ships the partially concentrated spar to an

[118]In 1955, Canada ranked third behind the U.S. and West Germany as a world producer. In that year, U.S. production of all grades accounted to 280,000 tons; Canada's output to 128,000 short tons. The latter was valued at $2.7 million.

affiliated company, St. Lawrence Fluorspar Incorporated whose flotation plant is located in Wilmington, Delaware; St. Lawrence Corporation also has a flotation plant at St. Lawrence. Newfoundland Fluorspar Limited ships its partially concentrated spar to Arvida, Quebec, where the parent Company, Aluminium Company of Canada Limited, has a flotation plant." (The point to be emphasized is that neither Company is, at present, making metallurgical grade fluorspar in the St. Lawrence area).

Fluorspar production in this country has increased rapidly over the past half a dozen years. From 7,000 short tons in 1945, it jumped to 64,000 tons in 1949 and on to approximately 120,000 tons in 1954. As a result of an agreement made in 1952 between the St. Lawrence Corporation of Newfoundland Limited and the United States government, a further rise in both output and export was achieved. This agreement which called for the delivery of some 150,000 tons of acid-grade material has now been fulfilled. Pursuant to this order, extensive additions and improvements to existing mining, milling and primary processing facilities have been made both in this country and in the United States.

A few years ago, the Paley Commission reported that North American requirements were likely to outstrip the resources available on this continent. As late as 1952 it was thought that recourse would therefore have to be had to such by-product sources as phosphate rock. Since then, additional resources have been proven up here and in the United States. Imports have also increased considerably from other countries. Faced with mounting supply and a decline in price, the United States domestic industry appealed to the United States Tariff Commission for further protection. Though a split decision was rendered, the President finally ruled, late in 1956, that the United States industry was not presently experiencing serious injury. Though further hearings will no doubt be convened, it is to be hoped that this substantial market will remain open to Canadian producers.

One reason for confidence is the extent of our known reserves. Recent articles prepared by officials of the geological survey of Newfoundland have referred to that province's potential as "considerably in excess of 20 million tons", or again "in tens of millions of tons". These are amounts sufficient to maintain the present rate of output for another century at least. Further resources may also be uncovered. At St. Lawrence, fluorite mineralization is known to persist over several square miles and to persist to depths of several hundred feet. Numerous veins have been located, only a few of which have been developed. A substantial expansion and output could therefore be supported without necessitating the discovery and opening up of fluorspar deposits elsewhere in Canada.[119]

[119]Various fluorspar occurrences have been reported elsewhere than in Newfoundland. Several in the Madoc area of Ontario and one near Grand Forks, B.C., have been worked at one time or another.

The prospective size of the North American market for this mineral can only be guessed at. Aluminum production, as it increases, will be a major determinant. Steel production, in which fluorspar is required for the removal or slagging off of impurities, at present takes about 50% of the total. Meanwhile chemical firms, serving uranium processing and other needs, have been moving rapidly to the fore. They already consume about 20%. Most of the remainder is employed in the production of glass and ceramic products. A blended growth rate, taking into account the changing relative importance of these end-uses, might be of the order of 4% or 5% in a year. If this expectation is realized, fluorspar consumption might multiply by approximately threefold over the next quarter century. North American consumption presently is in the order of 700,000 tons annually. By 1980 it could, therefore, be in the vicinity of two million short tons a year.

Canada's probable share of this much larger market cannot be estimated with confidence. United States government stockpiling of Canadian material has ceased. Also, under pressure from domestic mining interests, United States imports may be restricted. Competition from other countries, notably Mexico, Spain, Italy and Germany, may further reduce Canadian export possibilities. On the other hand the economic and strategic advantages which would follow from the further development of efficient Canadian sources of supply may be such as to maintain the preferred position this country's producers presently enjoy in the United States. This being the case, Canadian export shipments may rise sharply over the next 25 years. Home consumption, meanwhile, should increase at least at a 5% per annum rate.

Notes

Virtually all commercial fluorspar consists of three grades, based on the content of calcium fluoride and certain specifications regarding impurities:

(i) acid grade, containing at least 97% calcium fluoride;

(ii) ceramic grade, containing generally not less than 93%; and

(iii) metallurgical grade, containing 85% or more calcium fluoride and 5% silica.

The duty on fluorspar entering the United States is $2.50 per long ton carrying over 97% CaF_2; the duty on metallurgical grade is $8.40 per long ton. Fluorspar enters Canada duty-free.

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(b) *Barite (Barium Sulphate)*

Barite, the principal barium mineral of commerce is used extensively in oilwell drilling fluids. It is also finding greater application in the manufacture of paints, in glass and as a raw material for the production of various barium chemicals and special construction materials.

Canada has a growing interest in this mineral because it is already being produced and exported in substantial quantities from Nova Scotia. Exports in 1955 were valued at approximately $2.3 million. Over half of this crude material went to the United States to be ground prior to use there. The remainder was shipped in approximately equal quantities to such Caribbean oil producing countries as Trinidad and Venezuela.

Despite the fact that the United States is potentially self-sufficient in respect to barite, imports presently account for about one-third of that country's requirements.[120] Though demand is increasingly rapidly, Canadian producers must vie with producers in Mexico, Italy, Peru, Yugoslavia, Greece, Brazil and Sweden, for this market. Located close to tidewater, with low mining costs and possessing extensive reserves, their outlook and that of the consumption of barite on this continent should therefore continue to be intimately related one with the other.

Consumption has more than doubled during the past decade. Deeper oil and gas wells will have to be drilled. As this use accounts for 75% or more of the total[121] it alone could support a continued 6% per annum increase in demand. Meanwhile barite may be used to a greater extent in the production of heavy concrete and as a filler with synthetic rubber in numerous new, large volume applications. Barite concrete shields may also be used extensively to protect civilian power and military installations against excessive radiation. Research in metallurgical and chemical utilization of barium metal, compounds and alloys may also result in its being demanded in larger tonnages. For these various reasons a substantial domestic and export market for this mineral must be envisaged.

The United States tariff militates against treatment prior to export. Presently $3 a long ton on crude material which sells at around $13, it steps

[120]World production in 1955 was approximately 2.6 million tons. U.S. production in that year was in the order of 1.1 million tons. U.S. imports, meanwhile amounted to 360,000 tons.

[121]The present pattern of barite consumption in North America is: drilling mud, 82%; chemical, aggregate and other miscellaneous uses, 12%; and paints, glass and rubber each approximately 2%.

up to \$6.50 a long ton on barite, ground or otherwise manufactured. This, in itself, is sufficient to discourage the United States firms which control this industry in Canada from attempting to ship anything more than concentrates to their customers abroad. Meanwhile, imports may continue to meet most of the needs of the oil industry in western Canada.

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(c) *Nepheline Syenite*

Twenty-five years ago, most all of the feldspar requirements of the North American glass and pottery industry were derived from pegmatites in which the feldspar occurs in crystals or masses large enough to permit the selection of clean lump material by hand-cobbing methods. More recently, with the progressive exhaustion of the large economically situated feldspar-rich pegmatites, improved beneficiating methods (including flotation and magnetic separation) have been employed to recover feldspar from rock which was considered little more than waste a few years ago. Supplementing these resources has been the utilization of nepheline syenite. The latter, produced near Lakefield, Ontario, by the Canadian company, American Nepheline Limited, is being used in place of and to thereby increase the amount of the commercially useful feldspar resources on this continent.[122]

Transportation factors have influenced the entry of Canadian-produced nepheline syenite into the United States market. Sales, so far, have been limited to consumers in the vicinity of the Great Lakes and down the Atlantic seaboard. However, more intensive use, together with further penetration into the northeastern United States feldspar market, holds promise for a continuing rise in Canadian exports.

Of particular interest is the fact that the Canadian deposits are relatively low in iron content. This enhances their value for blending purposes. Canadian exports currently account for about 20% of the United States consumption of feldspar material. Most of this material has, until recently, been destined exclusively for the glass container industry, the products of which have enjoyed a phenomenal increase in demand over the past few years.

Canadian exports between 1944 and 1948 averaged out at around 2,000 short tons. Thereafter they rose rapidly. By 1955 they had reached 114,000 short tons a year. Though doubts have been expressed in some quarters

[122]In 1955 Canadian production approximated \$2 million. Of this, all but about 5% went to the U.S.

(United States Bureau of Mines, *Mineral Facts and Problems,* Bulletin 556, 1956), the industry's own plans and other market evidence point toward a continuing expansion in both consumption and trade. American Nepheline Limited has laid plans to bring its output up to the 300,000 ton a year mark. Recently a second producer has also entered the Canadian field.

U. Cement

Cement is one of the principal structural materials covered in this report. It is also an important manufacturing industry, its value of output in 1955 being in excess of $64 million. Consuming raw materials valued at approximately $30 million, cement production now provides employment for around 2,800 Canadians.

Over the past decade cement has frequently been in short supply. Even though considerable additions were made in capacity, domestic production has, until recently, been unable to keep up with the tremendous upsurge in construction which has taken place. Demands of this order of magnitude were unexpected; but for a good reason. In the 13-year period from 1933 to 1945, cement consumption in Canada averaged out at around six million barrels a year. In 1945, just over eight million barrels were used. Since then, however, demand has more than trebled. In 1955 Canadian sales totalled approximately 25 million barrels.

Here we have an industry which, after carrying idle capacity for well over a decade, was suddenly called upon to add to its plant and equipment as never before. From 1933 to 1945, it ran at less than 50% of capacity. Postwar, as mounting expenditures on all types of construction have added to demand, the outlook has become much more encouraging. Existing facilities have been expanded and new plants built. Several new firms have also entered the field. Instead of a single large cement producing company dominating the scene, the likelihood is that by 1960 half a dozen major concerns will be manufacturing this structural material in Canada.

Looking ahead, it is thought that defence construction requirements may moderate in rate of growth, if not in total amount. House building activity may also become more closely related to population growth and family formation. On the other hand, highway applications, dam construction, further industrial growth and new uses for cement, may help to maintain something like the long-run historical rate of increase in consumption.

New uses will probably add to the amount of cement sold per capita. One significant development working in this direction is that of prestressing Portland cement concrete to make it more useful, particularly in girders and beams. Additional tensile strength gain in this way would remove some of the present limitations of the use of cement in bridge construction. Also

recently developed, for purposes of conserving steel, are the lightweight concretes. They make the lifting of prefabricated concrete shapes more feasible. Other noteworthy trends include improvement and wider use of soil in cement, the development of tilt-up and other methods of assembling prefabricated structures and the increasing use of air-entraining cement and concrete for improved durability under extreme conditions of freezing and thawing.

Relative to most other materials, the price of cement has steadily declined. Further economies are also in prospect. Those which may continue to improve cement's competitive position include the growing use of preheaters for the drying of kiln raw materials (thus saving fuel); the increasing use of air conveying systems for moving finished cement; and the improved heat transfer and heat recuperation equipment now available to the industry. A marked change toward longer kilns of higher capacity should be noted. There is also the prospect of natural gas in volume and at moderate prices. Use of this unique fuel will not only improve control conditions but also render the industry less vulnerable to future labour cost increases.

The simplest approach to the problem of forecasting future needs is, first, to project per capita usage and, second, to multiply this by population. It has its shortcomings, however. Between 1916 and 1925, average per capita consumption in Canada was 0.70 barrels. In the decade between 1926 and 1935, it was 0.75 barrels. In 1936 to 1945, it was only 0.50 barrels. Throughout the postwar years it has been more like 1.4 barrels per capita. The trick is in deciding whether to allow for or to ignore the exceptional falling-off in consumption which characterized the late 1930's and World War II years. The latter course was deemed the more advisable, given the Commission's assumption as to near full employment and a moderate to high level of defence spending.

Thus, average consumption per capita may approximate 1.75 barrels per annum over the next decade and reach 2.3 barrels in 1980. Thus, allowing for the appropriate national population increases, total Canadian demand might range between 30 million and 40 million barrels in 1965 and reach at least 50 million barrels in 1980.

By the end of 1957 the productive capacity of the Canadian cement industry may be in excess of 35 million barrels. Imports, which in recent years have been running at around two million barrels annually, may decline. Exports, meanwhile may not go up very much. Regionally, shipments may be made into the United States. However, considerations of distance and possible tariff or quota restrictions must also be borne in mind.[123]

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[123]Imports into the U.S. are subject to duties as follows: Portland and other hydraulic cements pay 2.25¢ a hundred lb.; white, non-staining cement, 3¢ a hundred lb.; other hydraulic cements not otherwise specified, 5% ad valorem. The average price per barrel of cement at the factory in Canada in 1955 was $1.20.

Exports of Canadian produced cement in 1955 were valued at $3.1 million.

Production costs in Canada do not differ greatly from those reported by most plants in the United States. In this country fuel costs may continue to be the higher of the two. Expenditures on electricity, on the other hand, may be slightly less. Wages are lower but, due to differences in plant size, labour costs could remain about the same.

An important qualifying feature is the high unit cost of transportation. Cement is a relatively cheap, heavy commodity. At the same time it is up against relatively high overland freight charges. In considering potential markets it is therefore necessary to choose between a small plant serving closely situated or a large plant supplying widely dispersed market outlets. It is generally felt that the effective radius of distribution of a given plant may be between 100 and 150 miles in heavily populated districts.[124] Elsewhere, and this applies to the greater part of western Canada, larger and more efficient installations may be required to serve sparsely settled territory.

Because of larger market agglomerations, cement distribution costs are lower in the United States. Thus it follows that, though mill prices in Canada may be equal to or even lower than those in the United States, laid-down costs to the consumer may continue to be higher in many parts of Canada.

Import competition has always been present. Lower wage rates in Europe, frequently augmented by lower equipment costs and larger sales volume, have enabled cement manufacturers in the United Kingdom and Continental Europe to sell appreciable tonnages in the Atlantic region and Quebec. Though ocean transportation charges may vary, overseas producers may therefore continue to maintain their exports to Canada at the several million ton a year level.

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V. Other Structural Materials

(a) *Sand, Gravel and Stone*

Prior to World War I, the sand, gravel and stone industry was small, scattered and comparatively unorganized. Since then, and particularly since the late 1930's, things have changed a good deal. Now producing more than $100 million worth of products, the sand, gravel and stone industry is

[124]The majority of today's cement plants are located on top of or close to suitable limestone quarries.

comprised of many large firms, some employing substantial numbers of people on a year-round basis

Better than 90% of its output enters the construction industry and is used to produce concrete, bitumen products and other building and surfacing materials. The remaining 10% is marketed for use in glass making or as moulding sand, ballast, etc.

The bulk of the industry's output is marketed at prices under $1 a ton. Hence it is characteristically a local industry depending on nearby rather than national markets. Foreign trade usually is negligible. However, small tonnages of special purpose sand commanding relatively high prices are imported from overseas sources.

Reserves of sand and gravel are large but unevenly distributed. Moreover, sand and gravel of the quality required by modern construction and other specifications are limited in certain areas of the country. The high transportation costs relative to mine value also help to limit the effective radius of a given operation.

Sand and gravel deposits of suitable quality contiguous to large projects or large and expanding metropolitan markets are tending toward depletion. In such instances increasing resort is being had to crushed stone. This involves the installation of expensive equipment.

As for the long-term outlook, there can be little doubt that this important sector of the mining industry will continue to expand more or less in line with construction generally.[125] Production, in other words, may increase at an average annual rate of between 3% and 4% per annum. Output may therefore increase to between two and two and one-quarter times its present level between now and 1980.

(b) *Lime*

Lime (calcium oxide) is obtained by calcining a limestone or dolomite and is used extensively as an alkali chemical and in other industrial applications. Smaller quantities are employed in mortar and plaster and as a soil conditioner. Lime is essential in many of its uses and therefore meets very little competition, except in the building trades. It is also used as one of the raw materials in the manufacture of calcium and magnesium metals.

Limestones are abundant and widely distributed in Canada. However, only limestones of high purity are usable for lime manufacture. Surface occurrences are, of course, preferred because of relatively low mining costs. However, in a number of the more thickly populated (and hence intensively

[125]The U.S. Bureau of Mines study entitled *Sand and Gravel*, 1956, remarks on the remarkable parallelism that has existed since 1915 between the output of sand and gravel and construction activity. It suggests that, because a modest lag has developed in recent years, it might be safe to assume that demand for sand, stone and gravel products might now grow at a slightly lesser rate than construction activity in general.

exploited) areas of the United States producers already have been obliged to resort to underground operations.

A review of consumption trends is useful. Though the chemical industry's requirements are by now far the largest, they have only recently passed their World War II level. Refractory requirements, the second largest use, have been mounting steadily. Building applications, third in line, have edged up slowly. Agricultural usage, meanwhile, has actually declined according to the latest available United States statistics.

A significant long-run trend in the lime industry is toward fewer and larger plants. Another marked tendency is one involving usage. Many years ago the building trade consumed most of the lime and chemical uses were relatively few. Over the past quarter century, chemical applications have moved progressively to the fore. Meanwhile greater quantities are being used in road stabilization and in treating industrial wastes.

Canadian lime production in 1955 was valued at approximately $15 million. It is forecast as rising to approximately three and one-half times its present level by 1980, or at an average annual rate of approximately 5%. (This conclusion is based upon future trends as reported in the chemical and construction industry studies.) Some further increase in calcium metal production is also envisaged.

6

RESERVES AND RELATED SUPPLY CONSIDERATIONS

A. Introduction

The preceding chapters have traced the growth of Canada's mining and metal processing industries and shown the rising demands being made on them. Forecasts for the future indicate that both domestic and export requirements will force production steadily higher in the years to come. Consequently, consideration of the nation's reserves of metals and minerals; of whether these reserves can be maintained or increased as production mounts; and of the factors that may set a limit to the maintenance of reserves in the long-term future is of prime importance.

The most disconcerting feature of mineral deposits is that they are exhaustible. They are wasting assets that, as they are mined, must be replaced by new deposits if production is to be maintained or increased. Unlike products of the field and forest which can be reproduced in the same area, ore deposits cannot be reproduced; the mining industry must constantly turn to new deposits which, to be competitive in grade, may lie far distant in the less developed countries of the world. Thus many of the world's most highly industrialized countries are dependent already on external sources of supply; others are becoming net importers for the first time in their history.

The grade of material that can be mined profitably, and hence constitutes ore, depends on a number of factors subject to constant change. Thus, price of the metal or mineral is dependent on the demand or market, and price determines the grade of material that can be mined; advances in technology may make possible the economic treatment of material hitherto too low-grade or refractory to be mined; and particularly in less developed areas, new and lower-cost transportation, by lowering over-all costs, may change non-economic material into ore.

When prices of metals or other mineral products are low, only the higher-grade deposits can be worked profitably. As prices rise, a larger amount of material becomes commercial. Because the lower-grade material is much more plentiful, the mining industry may be pictured as descending

a pyramid the tip of which represents the richest deposits which are in limited supply and the base, the deposits of low-grade materials which are in large or practically unlimited supply. Thus, as prices rise the amounts of material that can be classed as ore commonly increase in large degree. Technological advances which make possible the treatment of lower-grade material, with no increase in cost of the end product, have the same effect.

The reader may imagine an ore body that grades by decreasing valuable metal content into the surrounding valueless country rock. As prices rise (or costs fall) the dimensions of the central core of material that can be profitably mined (the ore body) increase by the addition of formerly marginal material which, under these new conditions, has become profitable to work. On the other hand, falling prices and rising costs of production diminish the dimensions of the ore body without a ton being mined.

Beyond the marginal material may be that part of the deposit which, under present technological conditions and at prices and costs within the range of recent experience, seems unlikely ever to become ore. Yet the existence of this material cannot be ignored entirely. In the future, exceptional increases in demand (and thus price) or such technological developments as radical departures in mining methods, new techniques in metallurgical treatment or unforeseen uses for hitherto valueless by-products may introduce new conditions from those which today determine what is ore.

This chapter deals with mineral deposits and ore reserves that are known and, at least to some degree, have been measured and studied. It does not include consideration of deposits still to be discovered. For appraisal of the over-all mineral potential of the country we must turn to the available basic geological information about Canada. From it may be found the distribution of the rocks favourable or unfavourable for the occurrence of certain types of minerals, and the form and extent of structures that may be favourable sites for mineral deposits. This is discussed in Chapter 3 and Chapter 7.

In the sections that follow, the classification of ore reserves is discussed and Canadian reserves of the more important metals and non-metallic minerals are appraised and compared with world reserves. Brief reference is made to Canada's reserve position compared with current rates of production and consumption, and in some cases mention is made of known reserves of material not now of ore grade but which some day in the future may be a source of supply. In conclusion, the maintenance of Canada's present favourable ore reserve position is briefly discussed.

B. Classification of Ore Reserves

Before discussing Canadian ore reserves of the more important metals and minerals, some discussion of the different classifications of ore used in preparing the estimates is necessary.

The continuity of most ore deposits cannot be determined with any assurance simply from their geological environment. Furthermore, the metal content is likely to change in an unpredictable manner from place to place in a deposit. With the exception of certain bedded deposits, ore bodies must be measured and sampled at fairly close intervals to estimate their size and grade with reasonable accuracy. Therefore, in estimating reserves, certain classifications of ore are necessary that express the degree of certainty of the estimates in regard to tonnage and grade. The following classifications and definitions, after those of the United States Bureau of Mines and United States Geological Survey, have recently been approved by the United Nations Educational, Scientific, and Cultural Organization and are used by the Department of Mines and Technical Surveys, Ottawa.[7a]

> *Ore:* Mineral bearing material that can be mined at a profit to the operator or to the benefit of the nation under the conditions prevailing at the time of the appraisal.
>
> *Measured (proven) ore:* Ore from which tonnage is computed from dimensions revealed in outcrops, trenches, workings, or drill holes and for which grade is computed from adequate sampling. The sites for inspection, sampling and measurement are so closely spaced, on the basis of defined geological character, that the size, shape and mineral content are well established.
>
> *Indicated (probable) ore:* Ore for which tonnage and grade are computed partly from specific measurement, samples or production data, and partly from projection for a reasonable distance on geological evidence. The openings or exposures available for inspection, measurement and sampling are too widely or inappropriately spaced to outline the ore completely or to establish its grade throughout.
>
> *Inferred (possible) ore:* Ore for which quantitative estimates are based largely on knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. Estimates are based on assumed continuity or repetition for which there is geological evidence; this evidence may include comparison with deposits of similar types. Bodies that are completely concealed, but for which there is some geological evidence, may be included.
>
> *Potential "ore":* This includes known mineral deposits, the mining of which depends on improved prices, improvements in methods of mining or treatment, transportation facilities, etc. This material may be classified in the same way that ore is classified, or it can be treated much more generally.

Older definitions of *measured ore* may stipulate that the ore be exposed on four sides by drifts and raises that are close enough to leave little doubt

a Numbers refer to references in bibliography at the end of the chapter.

as to the continuity of the ore between them. However, modern exploration relies largely on drilling and the term measured ore is now generally applied wherever the continuity between drill intersections is practically assured. Nevertheless, there should be some exploration by underground workings in which the ore can be examined before it is classed as measured; where only drill hole data are available, the ore is usually classed as indicated rather than measured.

In regard to *indicated ore* there is an element of uncertainty, but this is related more to the accuracy of the grade, shape and tonnage of the ore body than to the presence or absence of ore. Indicated ore needs more development before the tonnage and grade can be estimated with the accuracy needed for measured ore.

Inferred ore includes ore that may exist in structures that have been tested only at wide intervals, or have not been tested at all. Much of it may be completely concealed and uninvestigated, and assumption of its existence based largely on geological speculation. Tonnage estimates of inferred ore are of doubtful value unless accompanied by explanations of the assumptions made and the risks involved. Although such estimates may be based on sound reasoning and future exploration may substantiate them, inferred ore cannot be regarded as a known reserve. In general, mining companies do not include inferred ore in estimates of reserves, nor are estimates of inferred ore released for publication by most companies. Inferred ore is not included in estimates of reserves used in this report unless specifically so stated.

Potential "ore" is not ore in the true meaning of the term because, although these deposits are known and at least in some degree measured and studied, they cannot be mined profitably under the conditions prevailing at the time of the estimate. With rare exceptions, deposits of such material are not included in the ore reserve estimates that follow; where they are included it is specifically so stated.

Measured and indicated ore make up the known reserves maintained in advance of mining, commonly in an amount geared to the rate of production of the mine. Young mines may rapidly develop more ore than they are mining. If this trend continues, the rate of production may be expanded. However, in the life of every mine the point is reached when reserves are maintained with difficulty and eventually the amount of new ore developed each year is less than that mined. The mine has then reached old age. It is only when a mine has reached old age that its total productivity is accurately known and even then new ore bodies may be discovered that will rejuvenate the mine.

On the other hand the total potential of youthful and mature mines cannot be forecast with accuracy; many operate for long periods without ever having a reserve of more than a few years ahead of them. Most mines in Canada, other than gold, are in the youthful to mature stage.

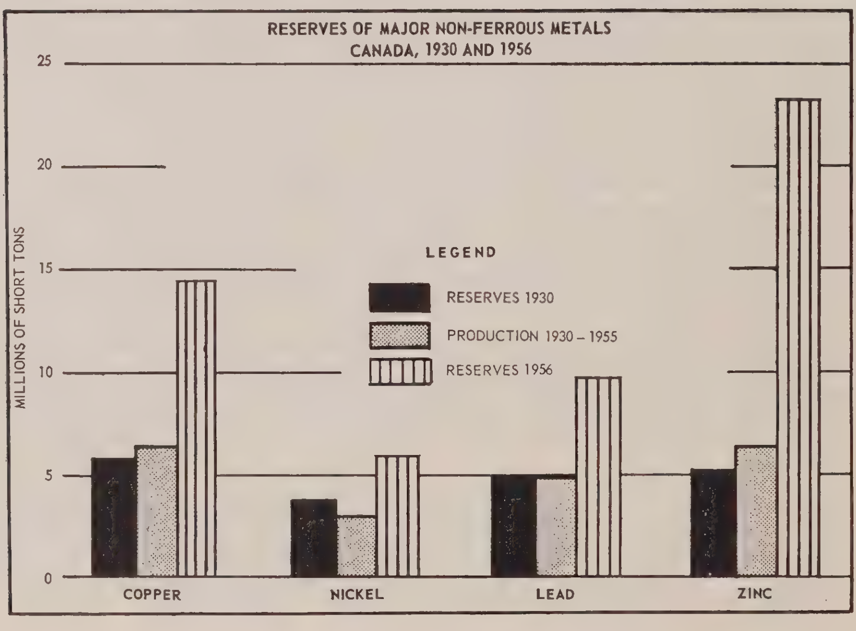
Ore reserves in themselves give but part of the over-all mineral potential of a country. They are based mainly on the known reserves of producing mines and of properties being prepared for production. Mining companies tend to maintain only sufficient reserves for operating security and efficiency. Exploration can be carried on most cheaply and efficiently a short distance ahead of production; to develop reserves far in advance of requirements not only increases the cost of finding ore but makes the job more difficult because exploration can be done most advantageously and under better guidance close to actual mining operations. Consequently, ore reserve estimates for most established mines tend to remain nearly constant from year to year. They reflect mining practice and current or near future production rather than over-all potential.

Table 33

COMPARISON OF ORE RESERVES, 1930 AND 1956

	Estimated reserves in short tons metal content		Reserves in terms of years' supply at prevailing rates of production in 1930 and 1956	
Metal	1930	1956	1930	1956
Copper	5,620,000	14,504,000	39	45
Nickel	3,730,000	6,027,000[a]	72	35
Lead	4,750,000	9,958,000[b]	29	50
Zinc	5,200,000	23,234,000[b]	39	54

a Does not include Mystery-Moak Lake deposits.
b Includes Pine Point deposits, Great Slave Lake, Northwest Territories.



This is illustrated by a comparison of known Canadian base metal reserves in 1930 and in 1956, and of total base metal production over the 25-year period 1930-55. (See Table 33; also chart entitled Reserves of Non-Ferrous Metals, Canada, 1930 and 1956.) Production in the 25-year period exceeded the 1930 reserves of copper and zinc and about equalled the reserves of lead; in the aggregate, production in these 25 years totalled 105% of the reserves of 1930. Had no further ore been developed, reserves would have been completely exhausted in the 25-year period. However, reserves have more than kept pace with production; by 1956, copper reserves had increased by 157% over those of 1930, nickel reserves by 62%, lead by 110% and zinc by 350%. Rates of production have increased and 1956 reserves in terms of years' supply at prevailing rates of production have changed also. Thus, the number of years' reserves at prevailing production rates have increased from 39 to 45 years for copper, from 29 to 48 years for lead and from 39 to 55 years for zinc. For nickel, the increase in rate of production has been particularly large. As a consequence, in spite of a large increase in reserves, the number of years' supply has decreased from 72 to 35 years. But the nickel reserve estimates do not include any nickel in large deposits being brought into production in the Mystery-Moak Lakes area. Were the reserves in these deposits included, present nickel reserves in terms of years' supply would be somewhat closer to those of 1930.

Ore reserves are thus of limited value in attempting to appraise the full mineral potential of a country, and particularly of a youthful and relatively undeveloped country such as Canada. However, they do give an estimate of the minimum amount of ore known to be commercially available at a given time; they also indicate the materials in present abundant supply and those in which the nation is apparently deficient. And over a period of years, the ratio of ore reserves to current production is of significance; if this ratio is being maintained or is increasing it suggests that the potential is adequate for the rate of production.

C. Reserve Estimates

(a) *Aluminum*

Aluminum is the world's most plentiful metallic element, making up 8% of the crust, but of the many aluminum minerals, only bauxite, an impure hydrated oxide (Al_2O_3, $2H_2O$) is commercially important as an ore of aluminum. The better bauxite ores, which are formed by decomposition by weathering of highly aluminous silicate rocks are found mainly in tropical to semi-tropical countries. Only easily accessible deposits with a content of 20% to 30% aluminum are economic at the present time.

Estimates of world bauxite reserves range from 1.8 billion to 2.7 billion tons or sufficient for well over 100 years at current rates of mining. During

the past 15 years new reserves have been developed at three to four times the rate at which bauxite is being mined.[8] Large areas in tropical and semi-tropical countries in South America, Africa and Asia have not been prospected for bauxite and without doubt the world's bauxite resources are very large.

Although Canada's aluminum production is second only to that of the United States and accounts for about 20% of the world's supply, all of it is produced from imported ore. No commercial deposits of bauxite are known in Canada, nor are any likely to be found. Because bauxite is a soft superficial deposit formed on the surface, any deposits that may have existed in the past in Canada have been destroyed by glaciation.

Materials other than bauxite, including anorthosite, nepheline syenite and clays, contain a high percentage of aluminum. Considerable research on the production of alumina from these materials was carried on during World War II and is continuing.[8] The extraction of alumina from these materials has been shown to be feasible but the processes so far developed require the handling of large amounts of raw material, a more complicated process, and plants of higher initial cost. As a consequence costs are higher. However, considerable progress has been made and in the future one or more of these materials may be used as an ore of aluminum.

Canada has practically unlimited supplies of anorthosite in Quebec, north of the St. Lawrence River, and large reserves of nepheline syenite in the Bancroft-Haliburton area of Ontario.

(b) *Asbestos*

Of current world production of asbestos, Canada produces about 64% followed by the Soviet Union with 16%, the Union of South Africa with 7%, Southern Rhodesia with 5% and the United States with 3%.[19] No estimates of the reserves of these countries, other than Canada, are available but those of the Soviet Union and Africa are probably large.

Canadian asbestos mines have measured reserves of 575 million tons of ore; indicated reserves are estimated at 379 million tons.[1] Reserves thus total 958 million tons (fibre recovery averages about 9% of the rock milled). In the past eight years alone some 250 million tons of new reserves have been found, or about three times the tonnage mined in that period.

With the additional milling capacity now under construction and planned, the average annual rate of depletion will be about 17 million tons of ore a year. At this rate of production, known Canadian ore reserves are sufficient for more than 56 years.

All but a small part of these reserves are in the Eastern Townships of Quebec. Ultrabasic rocks similar to those in which the Quebec deposits oc-

cur are also found in Newfoundland where exploration of known deposits is currently under way. Favourable rocks also occur at intervals from Chibougamau, Quebec to Cochrane, Ontario. One mine has been developed and other deposits of potential economic importance have been indicated. In western Canada ultrabasic rocks outcrop intermittently from southern British Columbia into the Yukon; asbestos is being produced by one mine and other deposits have been found recently and are being explored.

(c) *Copper*

No recent estimates of world reserves of copper are available but known ore reserves probably contain more than 100 million tons of copper. United States reserves alone are estimated at 25 million tons of recoverable copper in ore averaging less than 1%.[8] African deposits are large and high grade with much of the ore containing 3% to 6% copper. Chilean deposits are also very large, most of the ore averaging 2% copper.

Canada has a substantial part, probably in the order of 15%, of the world's known copper reserves. The Canadian copper reserves are in sulphide deposits that commonly contain other metals in addition to copper. Measured ore reserves are estimated to contain 8,749,000 tons of copper in ore averaging 1.34%; indicated reserves are estimated at 5,755,400 tons in ore averaging 0.90% copper. Total reserves are thus 14,504,000 tons of contained copper in ore averaging 1.12%. At the 1955 rate of production of 324,000 tons, known reserves are sufficient for about 45 years.

In addition to those reserves, several large but low-grade deposits are known. Large deposits in the Highland Valley area near Ashcroft in southern British Columbia range from 0.5% to 0.7% copper and are similar to the large and productive porphyry copper deposits of the United States. Exploration is proceeding to find out if these deposits can be mined at the present time. With reduced costs due to technological advances and the probable long-term increasing value of copper, the eventual exploitation of these and similar large but low-grade deposits seems likely.

(d) *Iron*

World iron ore reserves are large. They have recently been estimated[14] at 84.5 billion tons or sufficient for about 600 years at present rates of production.

Canadian reserves of iron ore are also large, so large that it is difficult to assess them quantitatively. In the Labrador-Quebec iron belt and Steep Rock Lake area, insufficient detailed drilling has been carried out on known iron ore occurrences for a complete estimate; but measured reserves of direct shipping ores are close to one billion tons. In the Wabana deposits of Newfoundland, measured, indicated and inferred reserves of direct shipping and

good-grade ore may total 4 billion tons and some estimates are as high as 10 billion tons.

In addition to the direct shipping ores there are immense reserves of concentrating ores ranging from 30% to 42% iron, mainly in the Labrador-Quebec iron belt but also as smaller deposits throughout Ontario and elsewhere in the Precambrian Shield. Beneficiation of these ores using modern techniques is simple in many instances. (See Chapter 7.) Some of the Ontario deposits are already contributing substantially to Canada's production, and further large-scale production in both Ontario and Quebec is planned. Reserves of these concentrating ores amount to many billions of tons.

Including only the reserves of producing mines and of properties being prepared for production by 1958, measured, indicated and inferred iron ore reserves may be conservatively estimated at 5,277 million tons.[9] The inclusion of ore on properties with less definite plans for production that have ore estimates based on widely spaced diamond drilling and geological interpretation would double or triple this figure.

Iron ore production in Canada in 1956 amounted to about 22.5 million tons. Production by the mid-1960's will probably be between 45 million and 60 million tons. At the 1956 rate of production of 22.5 million tons annually, reserves are sufficient for more than 250 years.

(e) *Lead*

The United States Bureau of Mines has estimated world reserves of lead-bearing ores to contain more than 40 million tons of lead.[8] This is adequate to meet world requirements for at least 20 years.

Not much information on the average grade of world reserves is available. However, United States reserves probably average less than 2% lead and 3% zinc; those in the central United States have a combined content of about only 2%. Grades are also fairly low in the older European mines. But in other parts of the world, including Canada, combined grades of 10% to 20% of lead, zinc and other metals are common. Thus one of the major Australian deposits averages 12% to 15% lead and 11% to 19% zinc.

Canada has nearly 23% of the world's lead reserves and is second only to Australia with 28%. For Canada, measured ore reserves are estimated to contain 7,277,000 tons of lead and indicated reserves 2,681,000 tons. The average grade is estimated at 4.06% lead for the measured ore and 1.75% for the indicated ore. Known ore reserves thus total 9,958,000 tons of contained lead in ores averaging 2.99% lead.[2]

Canadian estimates include 1.1 million tons of lead in the zinc-lead deposits recently outlined by diamond drilling and some underground work near Pine Point on the south shore of Great Slave Lake. Before these de-

posits can be exploited, some 430 miles of railroad must be built to the area; hence, because of present inaccessability, they fall into the classification of potential ore. These are replacement deposits in dolomitic limestone and are similar geologically to the highly productive Tri-State field of Missouri, Oklahoma and Texas.

At Canada's 1955 rate of production of about 201,000 tons of lead annually, known reserves are sufficient for about 50 years.

(f) *Nickel*

World nickel reserves are in ores of two main types, lateritic ores and sulphide ores.

Lateritic silicate and oxide deposits are the world's largest potential source of nickel. Deposits of such material totalling billions of tons exist in Cuba, New Caledonia, the Philippines, the East Indies, Dominican Republic, Venezuela, Brazil and the U.S.S.R.; smaller deposits are known in Japan, Madagascar and many other parts of the world. In Cuba alone the lateritic oxide deposits are estimated to contain 4,646,000 tons of nickel in material containing 1% or more nickel; reserves of material containing less than 1% are estimated to contain 13 million tons of nickel.[8]

The nickel in the lateritic deposits has been relatively costly to extract and, until recently, these ores were uneconomic to treat. However, nickel oxide is now being produced from the Cuban deposits on a commercial scale (31 million pounds of nickel as nickel oxide in 1956), and extraction will be increased to about 50 million pounds yearly in 1958 and perhaps to 100 million pounds yearly within a few years thereafter. Production of nickel from New Caledonia ores was 25 million pounds in 1956 and this may be increased substantially in the next decade.

By far the largest known reserves of sulphide ores are in the Sudbury district of Ontario. Probably the second largest are in the Mystery-Moak Lakes district of northern Manitoba, followed by the Finnish Petsamo deposits of the U.S.S.R. and smaller deposits in Canada, Southern Rhodesia and the Union of South Africa.

Canadian measured reserves are estimated to contain 5,037,000 tons of nickel in ore averaging 1.62% nickel; indicated reserves are estimated to contain 1,317,000 tons in ore averaging 1.21% nickel.[2] Total reserves thus contain 6,027,000 tons of nickel in ore averaging 1.42% nickel. At the 1955 rate of production of 174,000 tons, known reserves are sufficient for about 35 years.

However, in addition to these reserves, large nickel sulphide deposits have been developed recently in the Mystery-Moak Lakes area. The International Nickel Company, which controls these deposits, announced in De-

cember, 1956, that they will be brought into production by 1960. This will involve an expenditure of $175 million in the next three to four years and with developments in the Sudbury district, will raise the company's nickel producing capacity by 130 million pounds to 385 million pounds annually by 1960. No official estimates of the ore reserves on which this large operation is based have been released by the International Nickel Company. In regard to ore reserves, Henry S. Wingate, president of the company, has stated:[21]

> "It is too early to make a definite estimate of the final ore possibilities but sufficient ore has already been found to fully justify both the money we have already spent on exploration and the large amounts which we will have to spend to open these properties and put them into production. Our current exploration activities have shown there are fairly wide variations in the grade of ore in different parts of the deposits. By mining these ores on a schedule based on the policy of continuous operation over many years it will be possible to mine an average grade of ore which will compare favourably in nickel content with the ores we have been mining in Sudbury for some years. However, these deposits differ from our Sudbury ores in that they contain very small quantities of copper while the Sudbury ores are high in copper content.
>
> "The territory over which the favourable mineralization has been found is some 75 to 80 miles in length, with the width averaging approximately five miles. Further extensive exploration work will be necessary within the limits of the area which we have outlined."

Unofficially it has been reported[22] that production will be from two large deposits on which considerable development work has already been carried out. The Moak Lake deposit is reported to be 4,000 to 5,000 feet in length, up to 800 feet wide and to have been drilled to a depth of 2,000 feet. The Thompson deposit some 20 miles to the southwest is reported to be more than 15,000 feet in length, to range from 10 to 200 feet in width, and to have been drilled to a depth of 1,500 feet. Grade of the deposits is said to average 1.5% nickel.

Obviously the tonnage of ore in deposits of these dimensions is large. The magnitude of the developments under way to bring these deposits into production suggests that already substantial ore reserves have been developed and indicated. Eventually the nickel deposits of this area may prove to be comparable in size and importance to those of the Sudbury basin.

Nickel deposits in the Kenora district of Ontario, near Kluane Lake, Yukon Territory, and in the Coppermine River area, Northwest Territories, are currently being explored; and recently discovered deposits in the Cape

Smith-Wakeham River area of northern Quebec may prove important in the future.

(g) *Titanium*

Although titanium is the fourth most abundant metallic constituent of the earth's crust, only two minerals, ilmenite ($FeTiO_3$) and rutile (TiO_2) are of commercial importance. World production of ilmenite concentrates in 1955 was about 1.4 million tons. Chief producers were the United States 583,000; India 300,600; Norway 174,000; Canada 164,000 (titanium slag containing approximately 70% TiO_2); Finland 93,600; and Malaya 60,300 tons. World production of rutile concentrates in 1955 amounted to 75,500 tons of which 66,700 tons came from Australia and 8,500 tons from the United States.

Large deposits of ilmenite and ilmenite-iron ores are known in Norway, Canada, United States, India, Mexico, U.S.S.R., Africa, Ceylon, Malaya and Sweden. There will be no shortage of these ores in the foreseeable future on the North American continent or throughout the rest of the world.

The more important deposits of rutile are in beach sands; commercial deposits are known in Australia, Mexico, United States, Brazil and Africa. Most of world production in the past five years has been from Australia, with some from Florida. At present the North American continent is dependent mainly on Australia for this mineral. The Republic Steel Corporation has recently announced acquisition of deposits at Oaxaca, Mexico, containing a reserve of 25 million tons of rutile.

The world's largest known magnetite-ilmenite deposits are near Sokndal, Norway where the National Lead Company (U.S.) reports 300 million tons of ore indicated by drilling. Another large ore body near Tahawus, New York State, controlled by the same company, contains an indicated 100 million tons of ore. Magnetite-ilmenite (titaniferous magnetite) ore bodies of this type contain about 17% TiO_2.

Canada has the world's largest known ilmenite-hematite ore body at Allard Lake, Quebec. About 150 million tons of ore averaging about 35% TiO_2 and 40% iron[9] have been indicated by drilling. The ilmenite in this ore cannot be separated by mechanical methods of concentration and the ore is smelted to produce titanium dioxide slag running about 72% TiO_2 with desulphurized iron as a by-product. At the 1955 rate of production, when about 396,000 tons of ore were mined, present reserves are sufficient for more than 400 years.

With the exception of the Allard Lake ore bodies, no other significant commercial deposits of titanium ore have been found in Canada. However, there are many known deposits of disseminated ilmenite, ilmenite-hematite

and ilmenite-magnetite but the materials cannot be separated by inexpensive mechanical methods of concentration, and smelting is uneconomic. A combined mineral dressing-leaching technique applicable to low-grade titanium ores has been developed on a laboratory scale at the Mines Branch, Ottawa, but the process has not been tested on either a commercial or pilot plant scale.[9]

Canada has no known commercial deposits of rutile.

(h) *Uranium*

Since 1953, Canada's production of uranium has increased steadily, maintaining her position as one of the world's leading uranium producers. Recent developments indicate that this country will soon assume an even more prominent place among world producers and maintain this position for many years to come.

The sole purchasing agent of the Canadian government is the Crown-owned Eldorado Mining and Refining Company Ltd. The value of contracts between this company and 18 mining companies for the delivery of uranium before March 31, 1963 totals about $1.5 billion. At the end of 1956 Canada's uranium production had risen to the rate of about 3,300 tons a year; by the middle of 1958 it will be between 14,000 and 15,000 tons a year. By 1959 the gross annual value of uranium production will be between $300 million and $400 million and uranium may have risen from its present eighth place ($39,577,000 in 1956) to first place in dollar value among minerals produced in Canada.

Proven reserves of ore are in four main areas: the Great Bear Lake area in the Northwest Territories; the Beaverlodge area in northern Saskatchewan; the Blind River area in northern Ontario; and the Bancroft area in southeastern Ontario. In December, 1956, the Eldorado Mining and Refining Company estimated that Canadian measured reserves of uranium ore, together with a conservative estimate of indicated and inferred ore, totalled 225 million tons with a U_3O_8 content of 237,000 tons. By far the most of these reserves are in the Blind River area which is considered to have the largest proved reserve of uranium ore in the world. With the exception of the relatively small Eldorado Mine on Great Bear Lake, all Canada's reserves have been found and developed in the last 10 years—most of them in the last five years.

If prices for uranium increase, if certain areas become more accessible, and if cheaper methods of recovery of uranium are developed, large amounts of what is now submarginal material will become ore. Thus there are large tonnages of submarginal material in the Beaverlodge and Blind River areas; and in the Charlebois Lake area of northern Saskatchewan large bodies of submarginal pegmatitic material have been indicated by diamond drilling.

(i) *Zinc*

Measured and indicated reserves of zinc bearing ores in the world are estimated to contain more than 80 million tons of zinc. These reserves are adequate to meet world requirements for more than 20 years.

Canada has the largest zinc reserves in the world—23 million tons or 29% of the world total. These reserves are estimated to include 13,986,000 tons in measured ore with an average grade of 5.27% zinc, and 9,248,000 tons in indicated ore with an average grade of 3.50% zinc, or a total of 23,234,000 tons of zinc in ore with an average grade of 4.38% zinc.[2]

These estimates include reserves of 2.8 million tons of zinc in the zinc-lead deposits near Pine Point on the south shore of Great Slave Lake. Before these deposits can be exploited, a 430-mile railroad must be built to the area; hence because of their present inaccessibility they must fall under the classification of potential ore. Because of insufficient data, these estimates do not include any zinc in large, high-grade deposits discovered recently in the Snow Lake district of northern Manitoba.

At Canada's 1955 rate of production of about 428 thousand tons of zinc a year, known reserves are sufficient for about 54 years.

(j) *Reserves of Other Metals and Industrial Minerals*

Barite

Production of barite in Canada in 1955 amounted to 253,736 tons or about 11% of world production. In Nova Scotia the barite deposit at Walton is one of the world's largest, and several other deposits are known in the province. In British Columbia's Windermere Valley, large deposits are presently being exploited; other deposits too inaccessible to be worked are known in northern British Columbia. Total measured and indicated reserves in Canada are large, probably in the order of 6 million to 10 million tons.

Cadmium

In 1955, Canada produced nearly two million pounds of cadmium or about 11% of world production.

Cadmium is recovered in Canada as a by-product from the electrolytic refining of zinc at Trail and Flin Flon. The cadmium contained in the measured reserves of zinc ores in British Columbia, Yukon Territory, and Flin Flon district is estimated to be 43,268,000 pounds. The cadmium content of the zinc ores of eastern Canada are not included in this estimate; concentrates from these ores are exported.

Cobalt

With production of nearly three million pounds of cobalt in 1955 Canada is the world's second largest producer, following the Belgian Congo (19 million pounds in 1954).

Cobalt is produced in Canada from ores mined in the Cobalt area and as a by-product from the copper-nickel ores of the Sudbury and Lynn Lake areas. In general, production from the Cobalt camp except as a by-product from the silver ores is uneconomic unless at subsidized prices, and reserves are limited.

Reserves of cobalt contained in the copper-nickel ores of Sudbury and Lynn Lake are related directly to the reserves of these ores, which are large. The large nickel deposits of the Moak-Mystery Lakes area which are now being brought into production are reported to contain recoverable amounts of cobalt[21] and add substantially to Canadian reserves.

Columbium

Production of columbium in Canada has been of minor importance; only small quantities have been produced intermittently from pegmatitic rocks in the Northwest Territories. During the last few years, mainly as a result of the intensive search for uranium ores, several large deposits of pyrochlore (titanates and columbates of calcium, rare earths, uranium, etc.) have been found. These deposits are near Oka, Quebec; north of Nemagos, Ontario; and south of Golden, British Columbia.

The columbium pentoxide content of these deposits is estimated to be in excess of one billion pounds[9] (world production of combined Ta_2O_5 and Cb_2O_5 in 1955 was about 11.25 million pounds). However, these deposits are complex and much research on their metallurgical treatment remains to be done before any large-scale commercial production can begin.

Chromite

Canada has no known deposits of commercial-grade chromite ore. The Bird River deposits of the Lac du Bonnet district are large but low-grade. About 25 million tons of material containing 2,500,000 tons of Cr_2O_3 have been indicated by diamond drilling of several deposits. The deposits are of a bedded nature and known to extend for much greater lengths and probably greater depths than the parts drilled; they probably represent the largest known reserves of chromite in North America.[10] They have not been developed because they are sub-grade and cannot compete with imported ores. The chrome-iron ratio is below that required for metallurgical chromite and before these deposits are likely to be exploited, improved methods of beneficiation must be devised to produce from them a product acceptable to the metallurgical industry.

Gypsum

Crude gypsum production in Canada in 1955 amounted to 4,800,000 tons valued at $8.5 million.

Gypsum deposits of economic size are known in all provinces except Prince Edward Island and Saskatchewan. By far the largest deposits are in Nova Scotia where measured and indicated reserves are in the order of hundreds of millions of tons; with addition of inferred reserves the total in Nova Scotia probably exceeds one billion tons.

Large gypsum deposits are also known in the Bay St. George area of Newfoundland; near Hillsborough, New Brunswick; the Moose and Grand River areas of Ontario; at Gypsumville in Manitoba; the McMurray and Peace River districts of Alberta, and near Kamloops and Cranbrook in southern British Columbia.

Fluorspar

Almost the entire Canadian production of fluorspar is from Newfoundland (99% in 1955). Production in 1955 totalled 131,000 tons of fluorspar concentrates of sub-metallurgical grade from 235,000 tons of ore, or about 10% of world production.

No accurate estimate of Newfoundland's reserves has been made but they are known to be large and among the most important in the world. In the St. Lawrence area fluorite mineralization is known to extend over a length of three miles and to depths of 900 feet with no significant changes in grade or width. The higher-grade veins average four to five feet in width with a fluorite content of 95% or more, and silica content of 1% to 4%; the lower-grade veins are from 15 to 20 feet wide with a fluorite content of 75% and silicate content ranging from 10% to 15%. Based on geological studies reserves of ore have been estimated to exceed 10 million tons.[13]

Gold

At the end of 1955, total measured reserves of Canadian lode gold mines amounted to 56,300,000 tons with average grade of 0.297 ounces of gold a ton, or a gold content of 16,700,000 ounces. Gold contained in ore reserves of base metal mines and placer deposits are not included in the estimate, although base metal mines currently account for about 13%, and placer mines about 2%, of Canadian gold production.

Lithium

With the production of spodumene concentrates by Quebec Lithium Corporation from its mine in Lacorne Township, Quebec, in 1955 Canada became for the first time an important supplier of raw material to the lithium industry. The spodumene deposits of this property are considered to be among the largest known in the world. The main dyke has been traced for about two miles and, together with closely associated groups of parallel dykes forms an ore body with indicated reserves of 15 million tons to the

500 foot level. Average lithia content has been calculated to be between 1.2% and 1.3%.

In the Thunder Bay district of Ontario three companies have reported reserves in excess of one million tons each with lithia content ranging from 1.06% to 1.43%. In Manitoba, in the Winnipeg River-Cat Lake area, ore bodies in excess of eight million tons have been indicated by diamond drilling, and in the Herb Lake area more than five million tons averaging about 1.20% lithia have been reported. Pegmatite dykes containing lithium minerals are widespread in the Northwest Territories northeast of Yellowknife.

Magnesium

Magnesium is available in dolomite, magnesite, brucite and seawater of which there are abundant supplies in Canada and in many other countries in the world. In Canada, magnesium is being produced from dolomite at Haley, Ontario and from brucite mined at Wakefield, Quebec. Both minerals are in good supply and more than sufficient for the foreseeable future.

Manganese

Canada produces no manganese but has large deposits of low-grade manganiferous material. Of these, the deposits near Woodstock, New Brunswick, are probably the most important. Recent drilling is reported to have indicated 50 million tons of material to a depth of 500 feet averaging 10% manganese and 13% iron; an additional 100 million tons is inferred from gravimetric surveys with some confirmatory drilling. The treatment of these deposits, which extend into the State of Maine, has been investigated by both the United States Bureau of Mines and private industry. A triple smelting process developed by Dr. M. J. Udy and tested at the Mines Branch, Ottawa, shows promise and is being tried out on a pilot plant scale. If this process proves to be economic on a commercial scale Canada may become an important producer of ferromanganese.[9]

The Quebec-Labrador iron belt contains large deposits of manganiferous iron ore containing 4% to 12% manganese. Known deposits amount in the aggregrate to more than 100 million tons. Zones of manganiferous iron ore also occur in the iron deposits of the Steep Rock Lake area.

Mercury[9]

Canada used 203,756 pounds of mercury in 1954 and 419,592 pounds in 1955, all of which was imported, mainly from Mexico, Spain, the United States and the United Kingdom.

Mercury deposits of economic interest in Canada are limited to British Columbia. Pinchi Lake Mine is capable of producing 1,500,000 pounds

annually. This mine operated during the war years 1940-44; it could supply domestic requirements for many years if necessary, but cannot compete in price with foreign producers. The Takla Mine, 85 miles to the northwest of Takla Lake produced some mercury during the war years and in time of necessity could produce again.

The Canadian deposits average about 0.5% mercury as compared with grades of 5% to 6% in the Spanish deposits.

Molybdenum[9]

The Lacorne Mine near Val d'Or, Quebec is the only producer of molybdenite concentrate in Canada; it has a mill capacity of 600 tons a day. Production is more than double Canadian requirements. Reserves of measured and indicated ore are estimated at 480,000 tons grading 0.4% molybdenite.

In December, 1956, the company (Molybdenite Corporation of Canada) began operating a roaster to produce molybdic oxide that can be used by Canadian alloy steel manufacturers; plans for producing ferro-molybdenum and molybdenite based lubricants are also being studied. Heretofore all concentrates have been exported for processing.

At Boss Mountain in the southern Cariboo district of British Columbia, a molybdenite deposit apparently of substantial size and good grade is currently being explored. Near Shawville, Quebec, a molybdenite-bearing zone contains a moderate tonnage of moderate-grade material that could supply Canadian requirements in case of emergency.

Platinum metals

Canada and South Africa are the leading world producers of platinum metals followed by the U.S.S.R. All Canadian production (381,700 ounces in 1955) is a by-product from the treatment of the copper-nickel ores of the Sudbury basin. Based on recoveries from ore mined, the platinum metals content of the measured ore reserves of the Sudbury basin are estimated at 6,952,000 ounces, made up of 3,022,000 ounces of platinum and 3,930,000 ounces of palladium, iridium, osmium and ruthenium.

The platinum metals content of ore reserves of the Mystery-Moak Lakes nickel deposits which are being brought into production have not been announced. Unofficially the platinum metals content of these deposits has been stated to be about one-half that of the ores of the Sudbury basin.[22] These large deposits add substantially to Canadian reserves.

Phosphate

Production of phosphate in Canada is negligible. Deposits of apatite are found associated with mica in Ontario and Quebec near Ottawa but are

small and uneconomic to work. Deposits of rock phosphate are known along the Rocky Mountain divide near Crow's Nest, British Columbia but are too low-grade to exploit.

Potash

Potash deposits have recently been discovered in the Unity-Patience Lake area of Saskatchewan that rank among the world's largest. Considering only those areas with a five-foot bed within 4,000 feet of the surface containing 25% K_2O, reserves are estimated at 5,000 million tons of K_2O. Including beds at greater depths, which are of doubtful economic value, the deposits exceed known reserves in the rest of the world.

Selenium

The United States and Canada are the world's leading producers of selenium and are followed by Russia, Sweden, Japan and Northern Rhodesia. Canadian production of selenium in 1955 was 431,000 pounds valued at about $3.25 million; it is derived as a by-product from electrolytic refining of copper.

Canadian Copper Refiners Ltd., Montreal East, operates the world's largest selenium plant with a rated annual capacity of 450,000 pounds. The selenium is recovered from the electrolytic refining of copper anodes produced from copper ores mined in the Noranda area and from blister copper produced by the Hudson Bay Mining and Smelting Company Ltd. from copper-zinc deposits in the Flin Flon area. Selenium is also recovered at the Copper Cliff refinery of the International Nickel Company of Canada, Ltd. from copper produced from the copper-nickel ores of the Sudbury area. The Copper Cliff selenium plant has a rated annual capacity of 270 thousand pounds.

Silver

Canada, with production of 28 million ounces of silver in 1955 ranked third among world producers being exceeded by Mexico (45 million ounces) and the United States (35 million ounces).

More than 80% of Canadian production is by-product silver from base metal mines. The silver contained in measured and indicated reserves of base metal ores is estimated conservatively at 450 million ounces. This estimate does not include the reserves in mines producing less than 100,000 ounces of silver in 1956; nor does it include the silver in reserves of gold mines (gold mines account for 2% to 3% of the total annual silver production).

Sulphur

The three main Canadian sources of sulphur are: from pyrite obtained as a by-product in the concentration of base metal ores; from the sulphur

dioxide in smelter fumes; and from the hydrogen sulphide in natural gas which must be removed before the gas is marketed.

Noranda Mines Limited is the largest producer in Canada of by-product pyrite. The pyrite is shipped to sulphuric acid manufacturers in the United States and Canada and to the company's plant at Port Robinson, Ontario, where iron sinter, sulphur and sulphur dioxide gas is produced. There are, in addition, about ten other producers of by-product pyrite from the treatment of base metal ores. Reserves of sulphur in pyrite are related directly to reserves of base metal ores which are large.

In the smelting of base metal ores, large amounts of sulphur dioxide gas are produced which can be used for the manufacture of liquid sulphur dioxide, sulphuric acid or the production of elemental sulphur. In Canada sulphur dioxide is recovered from smelter gases at Trail by the Consolidated Mining and Smelting Co. Ltd., and at Copper Cliff, by Canadian Industries Limited. The amount of sulphur expelled in smelter fumes in Canada is tremendous; it has been calculated that the sulphur in the fumes from the stacks of the International Nickel Co. Ltd., Sudbury, alone, amounts to about 1.5 million tons a year. Research on the production of elemental sulphur from these stack gases is currently under way.

Western Canada has large reserves of natural gas some of which contains hydrogen sulphide. The hydrogen sulphide content of the natural gas of Pincher Creek, Jumping Pound and Turner Valley fields has been estimated at 8%, 4% and 2% respectively; other fields carry as much as 30% H_2S. Present plans for the distribution by pipeline of western natural gas means a large increase in production in the future and before this gas is marketed the sulphur content must be removed. Sulphur recovered from natural gas in 1955 amounted to 29,000 short tons; this will be greatly increased in the near future.

It has been estimated that within the next five years Canada's sulphur output from all sources may reach a total of 1,200,000 tons annually or double present consumption of about 600,000 tons.

The bituminous sands of northern Alberta are a large potential source of sulphur. These deposits have an average content of 5% sulphur which will be recovered if these deposits are developed.

Tin

Canadian consumption of tin is about 4,000 long tons annually; this is supplied by imports from Belgium, Malaya, United States, United Kingdom and the Netherlands.

A few tin occurrences are known in Canada including tin minerals in placer deposits in Yukon Territory and in pegmatite dykes in Manitoba, Ontario, Northwest Territories, Yukon Territory and Nova Scotia. All the

known pegmatite deposits contain less than 0.20% tin and are uneconomic to mine. Possibly in the future the alluvial deposits of the Yukon may become of economic interest when transportation facilities in and to the area improve.

The Consolidated Mining and Smelting Company produces about 200 long tons of tin a year as concentrates derived from the tailings in the concentration of lead-zinc-silver ores from the Sullivan Mine, Kimberly. The lead-zinc ore deposits of the New Brunswick Mining and Smelting Company are reported to contain small quantities of tin. When this mine reaches production it may produce tin as a by-product in about the same amount as is now produced at the Sullivan Mine.

Tungsten

Canadian shipments of tungsten concentrates amounted to 1,141 tons in 1955, or a little more than 1% of world production.

Canadian Exploration Limited which is mining three ore bodies near Salmo, British Columbia is the only Canadian producer. Most of its output has been sold to the United States government stockpile under a contract negotiated in 1951 when the price was considerably higher than that now prevailing; this contract expires in 1958.

Canadian reserves of tungsten are limited.

Vanadium

No vanadium deposits approaching commercial grade are known in Canada; all vanadium requirements are imported. Vanadium minerals are known to occur in minor quantities in a number of areas in Canada, one being in the iron formation in the Mine Centre area of Ontario, another being in association with the uranium deposits of Goldfields, Saskatchewan; none is of economic importance.

Zirconium

No zirconium deposits of economic value are known in Canada. Zircon occurs in small amounts in iron-rich sands on the north shore of the Gulf of St. Lawrence near Natashquan, Quebec. If, in the future, these sands are worked for their iron content a by-product zircon concentrate may be recovered also.

D. Summary and Conclusions

With the exception of aluminum, tin and phosphate rock, Canadian reserves of most of the more important metals and minerals are large. However, like the United States, Canada is deficient in reserves of certain additive or alloying metals that are extremely important to the iron and steel industry. Canada has no known reserves of vanadium or zirconium ores, no reserves

of commercial-grade manganese or chromium ores, and limited reserves of tungsten and molybdenum ores.

The magnitude of Canada's reserves of the major metals and minerals is shown in Table 34 and in the charts entitled Canadian Reserves and Production of Selected Minerals in Percentage of World Totals and in Years of Supply at Current Rates of Production. With nearly 15% of the world's copper reserves, Canada produces only about 9% of world output; with nearly 23% of the world's lead reserves, Canada produces less than 10% of world output; with 29% of the world's zinc reserves, Canada produces less than 14% of the world's output. In all these metals, Canadian reserves are being used at a slower rate than are the world's reserves as a whole. No data are available for world reserves of nickel, titanium, uranium or asbestos, but here also Canadian reserves in relation to world reserves are large.

Table 34

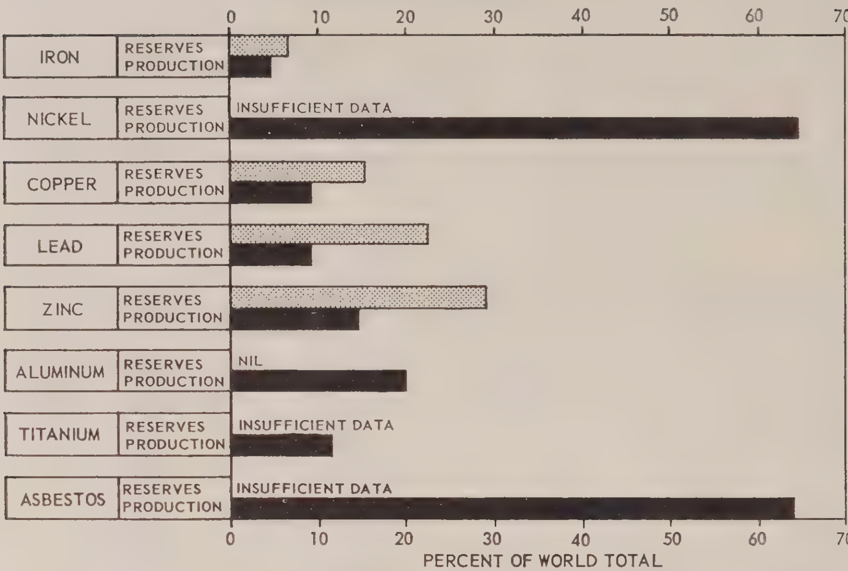
CANADIAN RESERVES AND PRODUCTION OF SELECTED METALS AS PERCENTAGE OF WORLD TOTALS

Metal	Production % of world total 1955	Reserves % of world total	Known Canadian reserves in terms of years' supply at 1955 rates of production
Aluminum	20.0	nil	nil
Asbestos	64.0	over 40	56
Copper	9.2	15.0	45
Iron	4.5	6.2	250
Lead	9.3	23.0	50
Nickel	64.5	over 40	35
Zinc	14.6	29.0	54
Titanium	11.5	over 20	400

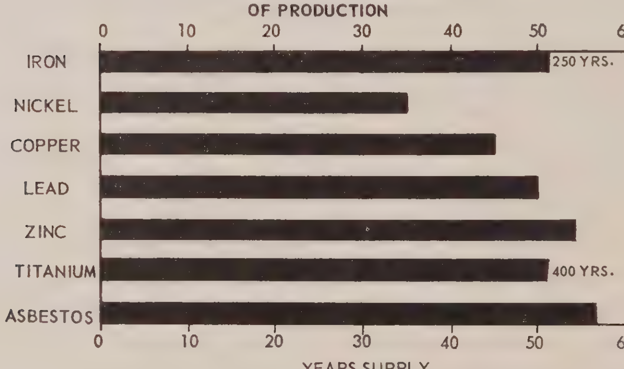
Although, with the exception of several of the additive metals, Canadian reserves of the more important metals and minerals are substantial, the search for new deposits must be pressed vigorously (a) to supply the greatly increased demands for the future as our own and the world's populations increase and the material standard of living rises; (b) to establish reserves of metals and minerals in which Canada is at present deficient; and (c) to establish sources of metals and minerals not in present large demand but that, in the future, may be of increasing importance (as was true of uranium a few years ago).

Most of Canada's present mines are but a few hundred miles beyond the main centres of population within a westerly trending strip that includes only the southern third of Canada (see maps entitled Principal Mining Areas of Canada). On the other hand, the main geological regions trend north-south. The concentration of producing mines in the southern third of Canada is the consequence of more thorough prospecting and lower costs of development and production in this more accessible region. There is good reason to expect that the northern regions will be found to contain a comparable number and variety of mineral deposits. Furthermore the mineral potential-

CANADIAN RESERVES AND PRODUCTION (1955) OF SELECTED METALS AND MINERALS IN PERCENT OF WORLD TOTALS



CANADIAN RESERVES OF SELECTED METALS AND MINERALS IN YEARS SUPPLY AT CURRENT RATES OF PRODUCTION



ities of the southern third of Canada are far from exhausted. This has been demonstrated by the number, size and variety of deposits found in the last decade by conventional and newer geophysical and geochemical prospecting techniques. (See Chapter 7).

The nation's over-all mineral potential can be viewed with optimism. Canada has large regions geologically favourable for finding new deposits, and experienced, aggressive and wealthy mining companies eager to find and bring to production, new mines.

Providing the economic incentives remain, we have good reason to expect that Canada's known ore reserves in 1980, in terms of year's supply at the increased rates of production likely to prevail at that time, will be comparable with those of today.

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7

TECHNOLOGY AND THE FUTURE

TECHNOLOGY has been defined as the science of the industrial arts. It comprises the techniques and processes by which man mobilizes the resources at his disposal and puts them to use. Technology is constantly striving to, and succeeding in, raising the material standard of living by supplying more abundant and more readily attainable supplies of needed materials. In the mining and mineral processing industries, the role of the technologist is to assure adequate supplies of ores and minerals and make them available at the lowest possible cost. His task is to reduce the labour and cost of finding, mining and processing the ore.

In the mining and mineral processing industries, the technological demands and efforts to meet these demands may be divided into four categories:

> *New techniques for the discovery of ore deposits.* The existence of most ore deposits being mined at present was indicated by surface exposures. Many more deposits, although reaching the surface, are covered by soil and overburden, and others are buried in the bedrock. Techniques for finding these hidden ore bodies are being developed.
>
> *Advances in mining practice.* By lowering costs, improved mining methods allow exploitation of lower-grade ores.
>
> *Improvement in the extractive processes.* The treatment of ores presents a constant challenge to the metallurgist to increase the recovery and purity of the product, to recover and find uses for by-products, and find means of economically treating low-grade marginal ores.
>
> *New and substitute materials.* Research is constantly in progress to find ways of recovering and using new materials that may substitute for, or replace, scarce or expensive ores.

This chapter considers briefly the opportunities and the problems in technology in these four fields; the advances that recently have been made and likely will be made in the next 15 to 25 years; and the probable impact of development of new techniques in the mineral industry on Canada's economy.

A. *New Techniques for Discovery of Ore Deposits*

Canada has been, and still is, singularly fortunate in having many hundreds of thousands of square miles of largely unexplored and unprospected country underlaid by rocks potentially favourable for the occurrence of mineral deposits, oil and gas. Most of our producing mines are mining ore bodies indicated by exposures at the earth's surface. They were found by prospectors with knowledge, skill and perseverance, but without many of the tools possessed by the modern prospector. The modern prospector is armed with geological and geophysical maps that guide him to the more favourable areas; with Geiger counters, magnetometers and other geophysical instruments that help find hidden deposits even though they are covered by soil and overburden; with chemical kits that allow him to track down ore deposits by testing for trace amounts of metals derived from them which form a surrounding halo in the overlying or nearby soils, in the vegetation, or in the streams. Likewise, the finding of structures favourable for the accumulation of oil and gas is no longer entirely dependent on mapping the exposed rock strata; the geological interpretation of seismic, gravity, magnetic and other geophysical data reveals the structure of strata several thousands of feet below the surface.

As our northern frontier is pushed back, the unexplored, unprospected areas become less and less, and the potential number of exposed and easily found ore bodies fewer. We will become increasingly dependent on new geological. geochemical and geophysical techniques that aid in finding concealed and buried ore bodies impossible to find by search with pick and shovel alone. Many such techniques now in use were unknown a few years ago, others are in the experimental stage; and we may confidently expect that many others are yet to be developed.

The prospector in his search for mineral deposits is aided by technology in many ways but most of them fall into one of four categories, namely: geology and geological mapping; air-photographs; geochemistry; and geophysics. In the final analysis the diamond drill must prove the existence and extent of ore indicated by these techniques.

(a) *Geology and Geological Mapping*

Geological maps present the basic geological facts about an area. Such maps. and the reports that generally accompany them, are indispensable in

helping prospectors choose areas in which to work and in guiding them in the field. They indicate areas that are favourable in a general way for a particular metal or mineral, and the position of formations and geological structures that are particularly favourable; and they show and describe the mines and prospects, if any, in the area. Geological maps are also essential for the interpretation of geophysical data, and the rapidly growing use of airborne magnetometers and electromagnetic gear has meant a greatly accelerated demand for the geological mapping of Canada.

Geological maps are prepared on various scales. In general, unmapped areas are first surveyed on reconnaissance scales of one inch to four, eight or 16 miles. These scales permit a preliminary evaluation of mineral potentialities, outline major structures and belts of favourable rocks, and afford data vitally needed for the intelligent planning of future geological and developmental work. Selected smaller areas, expected to hold particular promise of commercial mineral deposits or to afford critical scientific data, are mapped on more detailed scales ranging from one inch to one mile to engineering scales of one inch to 100 feet or less.

Most of the geological mapping on reconnaissance scales and the more detailed areal studies on one inch to one mile or less are carried out by the federal and provincial geological surveys. The detailed geological mapping on engineering scales is done mainly by the mining companies. Such detailed studies by the mining geologist both on surface and underground, form the basis for the exploration and development that first finds enough ore to justify production and then maintains reserves of the mine in advance of production.

Geological mapping and study is a form of basic research. The maps and reports present fundamental geological facts that are permanently useful and capable of reinterpretation from time to time as advances are made in the science of geology, and new mineral discoveries are made.

Most of Canada, including large regions in the northern part of the Precambrian Shield, the Arctic Islands and northern British Columbia, is as yet geologically unmapped. As recently as 1940, only 11% of Canada was geologically mapped on reconnaissance scales; and at that time it was pointed out that with no increase in the speed of mapping it would take 800 years to map the remaining 89%.[1a] But within the past five years a great change in mapping methods has taken place. In this period, by the combined use of helicopters and conventional aircraft, four areas have been mapped in reconnaissance by the Geological Survey of Canada in the relatively inaccessible northern barren grounds and Arctic Islands amounting in the aggregate to more than 300,000 square miles. Each of these areas might have required 25 to 30 years to map by conventional ground methods.

a Numbers refer to references in bibliography at the end of the chapter.

The helicopter technique has been fully proven in the mainland barren grounds and the Arctic Islands, and plans are in hand to adapt the method to geological mapping in two other physiographic regions—the mountainous areas of British Columbia and Yukon, and the vast timbered Mackenzie River valley. If, as expected, these trials prove successful, a rapid and efficient reconnaissance technique will be available for most geologically unmapped regions.

The Geological Survey of Canada hopes to expand its mapping programme to include two to three such helicopter operations each year. Such an expanded programme would make possible the complete reconnaissance mapping of Canada within the next 25 years. This would go far to meeting the immediate demands of the mining industry for geological information on remote areas. It would also permit a preliminary estimate of our mineral potentialities which at present, with more than one-third of the country geologically unmapped, is difficult to make.

One of the main difficulties confronting such an expansion in geological mapping, apart from securing the appropriate funds and authorization for increase in the establishment, will be the procurement of technical staff and service staff in special categories. Suitable scientific staff cannot be obtained on short notice and by sporadic recruitment. Any substantial expansion requires long-range plans that will ensure continued staff recruitment as qualified men become available regardless of the year to year fluctuations in exploration and development activity in the mining industry.

In addition to the promise of an accelerated rate of geological mapping by use of new techniques, we may confidently expect increased aid from geology in the search for ore deposits as more is learned about their origin. Up to now the search has been largely empirical; the more that is learned about why ore deposits are where they are, the more proficient will the prospector become in the search for new ones. Perhaps this requires some elaboration.

The search for mineral deposits is guided by two differing although related geological factors: namely, structure and genesis. Structure controls the localization of a deposit; it may be the favourable bed or fault along which ore minerals have been deposited; or the fold or stratigraphic trap that controls the migration and accumulation of oil. In the past 20 to 30 years emphasis has been placed on structural studies because they have proved the most practical and immediately fruitful method of finding ore deposits. On the other hand, little progress has been made in our knowledge of the genesis of ore deposits, although knowledge of origin and how and why they formed should be as important as the structures that localize them. The future will see modern chemical and physical techniques applied to an increasing degree to fundamental studies of sedimentation, metamorphism,

petrology and analogous lines of research. From these much will be learned about the geological processes responsible for the formation of ore deposits. For example, isotopic analysis of sulphur, lead, and many other elements may be found useful in the study of the migration of elements in the rocks of the crust and of the chemical factors that have led to their concentration as ore bodies; greater knowledge of the geochemical association of the elements may suggest the most likely rocks in which to search for ore bodies; and development of methods of determining the ages of minerals and rocks will be of great aid to the field geologist in studies of the stratigraphic sequence, the structure and the history of the rocks of the earth's crust.

Such basic research gives little promise of immediate monetary reward; it cannot be justified in its immediate usefulness in finding ore bodies. Nevertheless, advances in any science must come from the search for theoretical knowledge of this kind rather than the search for specific answers to practical problems. Such basic research should be stressed in our universities and by the federal and provincial geological surveys. With a better understanding of these processes, the development of new techniques will follow which will be as useful in leading the prospector to hidden ore bodies as structural studies are at present, and have been in the past.

(b) *Air Photographs*

Most of Canada has been photographed from the air, at least in preliminary fashion; and much of it has been, and will continue to be rephotographed as better cameras and techniques are developed. Air photographs greatly assist both ordinary and special prospecting. Where geological maps are not available, air photographs give much useful topographical and geological information to the prospector. Even where good geological maps are available, photographs show the position of rock outcrops and depict such geological structures favourable for prospecting as fractures, faults and folds in a way that is impracticable to show on a geological map. Many mining companies prepare, or have prepared for them, air photographic mosaics of the areas they plan to prospect which are used as a base on which all available geological information is plotted. Air photographs may also be enlarged and used as base maps for detailed geological mapping.

As yet, little use has been made of air colour photography for prospecting in Canada, although it has been used with some success in other countries. Under the climatic conditions prevailing in Canada it may not prove as useful as in dry arid regions, but will probably find increasing application in the future.

(c) *Geochemical Prospecting*

Geochemistry is the study of the chemistry of the earth including the elements of which the rocks and soils and waters of the crust are composed;

it is thus a part, or phase, of geology. Geochemical methods of prospecting are based on the fact that very small amounts of one or more metals in an ore body are likely to be dispersed in its vicinity. These traces of metals may be detected in the rock surrounding the ore body, in soil derived from these rocks, in streams, ponds or other bodies of water that percolated through such soils or rocks, or in plants growing in the soil. An unusual concentration of metal occurring in one of these ways is called a geochemical anomaly. A small amount of metal in the rock surrounding a mineral deposit is called a primary dispersion halo or pattern. An ore body may break down and traces of it be found anywhere between the ore body itself and the sea; this is known as a secondary dispersion pattern or halo. Such dispersion haloes may be indicated by geochemical anomalies in rock, soil, water or plants. The geochemist must select the medium or media best suited for the discovery of an anomaly of the specific element for which the search is being made.

Geochemical methods had not been used to any extent in Canada until the last four or five years, probably because of their reduced effectiveness in a country where the overburden is of glacial rather than residual origin and where much of the ground is permanently frozen. Nevertheless, some universities and government organizations have carried out research to appraise the methods as applied to Canadian conditions, to improve them, and to develop new ones. Several of the larger mining companies are now carrying on geochemical prospecting, especially in the investigation of electromagnetic anomalies in drift covered areas. It has been found that where direct sampling of soils is ineffective because they are glacial in origin, geochemical sampling may be applied to the clays or silts in the stream beds of the drainage system and small amounts of metals in them traced upstream to their source in much the same way as a prospector makes use of float in stream gravels. Without doubt geochemical methods will be used to an increasing degree by mining companies in the future with field parties trained in modern colorimetric, spectrographic and conventional chemical methods of analysis, and equipped with mobile field laboratories.

Many new and rapid methods of analysis adaptable to field conditions undoubtedly will be developed in the future and more will be learned about correctly interpreting the geochemical data. One may expect such new applications of geochemistry as the use of isotopic tracer techniques to study the circulation of underground water channels and thus locate faults and veins. Isotopic analysis of sulphur, lead and many other elements may be used in the future to study the migration of elements in rocks and the chemical factors that have led to their concentration, a field about which little is known at present. Much also remains to be learned about the geochemical association and cycle of the elements; from such studies, more may be

learned about the most likely areas to search for concentrations of specific metals.

(d) *Geophysical Methods*

Geophysical methods do not find ore bodies directly; they find anomalies which may or may not indicate ore bodies. Anomalies are irregular or abnormal values for the particular phenomenon that is being investigated, as, for example, a local distortion in the earth's magnetic field, or in an artificial electric or electromagnetic field. Such anomalies may be produced by ore bodies; they may also be produced by a variety of such natural phenomena as magnetic rocks rather than iron ore in the case of magnetic anomalies, and such non-sulphide bearing conductors as faults, graphitic zones, or by zones of uneconomic sulphides in the case of electromagnetic or electrical anomalies. Thus, at best, geophysical methods merely point out small anomalous areas where there is an increased possibility of finding ore or petroleum. Each anomaly should be investigated fully, when possible, by geological and other geophysical and geochemical methods before the final tests of diamond drilling and underground exploration are justified.

The present acceptance of geophysical prospecting methods in Canada is due in large part to successes achieved in the last ten years. These successes are related to the introduction of airborne geophysical methods which have been effectively followed by ground geophysical investigation and drilling. Thus the airborne magnetometer was used extensively in the search for magnetic iron ore in Ontario and Quebec and an anomaly on a published government aeromagnetic map led to the discovery of a large magnetic iron deposit at Marmora, Ontario. Ground magnetic and electrical methods played an important part in the discovery and development of the base metal deposits at Lynn Lake. The delimitation of the Steep Rock iron deposits was helped considerably by the ground magnetometer. Magnetic and electromagnetic methods have played a most important role in discovery of large base metal deposits near Bathurst, New Brunswick, and electromagnetic methods are credited with finding large nickel deposits at Moak Lake and zinc and copper deposits in the Snow Lake district.

Geophysical techniques have been used for many years in both mineral and petroleum exploration, but their success and acceptance came first in petroleum exploration. Worldwide geophysical investment in petroleum geophysics in 1954 was $350 million, compared with but $6 million for mining geophysics.[2] However, of the world total of $6 million spent on mining geophysics, $2,350,000 or 30% was spent in Canada. Although the total amount spent for prospecting for minerals in the United States exceeds that in Canada, the amount spent in geophysical prospecting for ore in Canada exceeds that in the United States. Canada is thus a world leader in the appli-

cation of geophysical methods to finding ore bodies, particularly in the development and use of airborne geophysical equipment.

Many of the major mining companies in Canada are now spending about 25% or more of their exploration budget (including cost of diamond drilling) on geophysics. Within the past few years, instead of being regarded as something separate from normal prospecting it is woven into the over-all exploration programme along with reconnaissance and detailed geological mapping, geochemical work and diamond drilling.

The need for more research on the interpretation of geophysical data is pressing. Many geophysical data have been compiled but because of lack of knowledge of methods of interpretation the best use is not made of it. Better methods are needed for the mathematical treatment of force-field measurements to delineate anomaly sources; more research is also needed on the correlation between the physical properties of rocks and their geochemistry and petrography.

(i) *Magnetic methods*

The magnetic methods are the oldest and most generally useful for investigating partly and completely drift covered areas. Several magnetic ore bodies have been found by this method, which is effective to a depth of about 500 feet depending on the size and type of deposit.

The airborne magnetometer which came into widespread use in Canada about 1948 is used largely to obtain regional information and to supplement conventional geological mapping. Under favourable conditions the magnetometer can be used to trace geological contacts and structures beneath areas of overburden, and to calculate the thickness of sedimentary basins and the contour of buried basement surfaces. The Geological Survey of Canada has had a magnetometer equipped aircraft since 1947. Recent practice by the Survey has been to use the airborne magnetometer in advance of conventional mapping, thereby permitting geologists to plan and conduct surveys with the maximum advance information; and thus prepare more complete and accurate geological maps than would otherwise be possible, particularly in areas of widespread overburden. As a prospecting tool, aeromagnetic data together with reconnaissance geological information can be used to select areas worthy of more detailed examination. A great deal still remains to be learned about the interpretation of aeromagnetic data through field and laboratory research. As more is learned the magnetometer will come into even wider use.

(ii) *Electromagnetic methods*

The electromagnetic method has become widely used in Canada in the past few years in the search for massive sulphide ore bodies. Of all now

known geophysical prospecting methods, it probably holds the most promise for future development because of its versatility and adaptability. Because it is not necessary to make physical contact with the ground, the gear can be used from aircraft and is light enough in weight to be used in helicopters. Electronic devices add to the versatility of the method and rapid developments in the electronics field will continue to improve the instrumentation. Electromagnetic methods locate conductive bodies. At present airborne electromagnetic gear can locate conductors within about 100 feet of the surface. Ground techniques can carry the effective depth of exploration down to several hundred feet.

The rate at which this promising technique has been developed recently is the result of the great demand for base metals; the extent to which it will be applied and developed in the next decade will relate directly to this demand. If the present demand is sustained, keen competition will develop among the large mining companies in Canada to be first to cover the more favourable areas with airborne electromagnetic gear and to investigate the more promising anomalies that are found; a competition which may prove more keen than that of the past few years to detect magnetic anomalies in the search for magnetic iron ore bodies. In fact, spurred on by the success of electromagnetic methods in helping to find large ore bodies in New Brunswick and northern Manitoba, this race is already on. From 1949 to 1955 only one aircraft in Canada was equipped with electromagnetic gear. Within the past year (1956) no fewer than 15 aircraft have been so fitted and by 1958 there may well be as many as 30. By 1960, if the present drive is maintained, many of the more obvious electromagnetic anomalies within reasonable distance of ground and water transportation will have been detected. These anomalies, which may well number in the thousands, will be caused by conductors of various kinds including faults and shear zones, graphitic zones and bodies of massive sulphides. (Disseminated sulphide deposits, many of which may be of ore grade, are not detected by present electromagnetic methods.) Of these, only the massive sulphide deposits are of economic interest and some will not be ore.

The electromagnetic method has not been used enough to justify a forecast of the percentage of the anomalies that will indicate ore bodies. However, if but 1% indicates ore bodies, target areas will be greatly reduced. This will allow concentration of intensive search in these most likely places and as a probable result many new ore bodies will be found.

(iii) *Other geophysical methods*

Other electrical methods include the resistivity and self-potential methods. Resistivity methods are somewhat more useful than the electromagnetic method for obtaining structural information but overburden and permafrost

create serious problems. Resistivity methods are also slower and more expensive than electromagnetic and cannot be used in aircraft.

The self-potential method has been used to some extent for more than 30 years but much remains to be learned about it and the interpretation of the anomalies that are obtained.

The gravity method became practical for mineral prospecting with the development of the lightweight gravity meter about 1947, and since then has been used as a primary method for base metal and iron ore prospecting with rather limited success. The necessity of extremely accurate elevation control and arduous corrections has made it unpopular and expensive, and these difficulties are accentuated by rugged terrain. Also, over areas of overburden it is difficult to tell whether anomalies are caused by irregularities in the bedrock surface or by density changes within the bedrock. Economic solutions to both these problems undoubtedly will be found.

Because of its high cost, some companies are using the gravity method as a secondary geophysical tool to check anomalies found by other methods. For instance, if an electromagnetic anomaly is detected and it is not known whether it is due to graphite or a deposit of metallic sulphides, a single gravity profile over the anomaly can sometimes eliminate the ambiguity.

Regional gravity surveys of the type done by the Dominion Observatory will find increasing use for regional studies.

At present prospecting for radioactive minerals on the ground with Geiger or scintillation counters is confined to rock outcrop areas; the detection of radioactive deposits beneath more than a foot or so of overburden is not feasible because the gamma rays emitted by radioactive minerals are absorbed and do not reach the surface. Ground water may dissolve radioactive minerals from buried rocks and percolate to the surface where the radioactive material may be precipitated and thus indicate a source at depth, but much more must be learned about ground water movement and the geochemistry of the radioactive minerals before this method will be of practical use.

Scintillation counters used in aircraft flying over the Canadian Shield about 500 feet above the ground detect many anomalies but ground investigation shows most of them to be caused by outcrops of radioactive granite with much too low a uranium content to be economic. It has been found also that the radiation from these rocks tends to swamp the effects that might be expected from higher-grade deposits of economic interest which are generally exposed over only small areas. Research is now in progress on ways of separating the effects of radiation caused by the naturally occurring radioactive elements, uranium, thorium, and potassium. If successful, the airborne

radioactivity survey will become a useful prospecting tool for uranium and other radioactive deposits.

(e) *Future Trends in Prospecting and Rate of Discovery of Ore Deposits*

It is still a worthwhile venture to prospect with pick and shovel throughout large areas in Canada, but the chance of finding promising showings with these tools alone is becoming less. To find the mines of the future it will become more and more necessary to resort to prospecting methods that indicate the presence of mineral deposits covered by lakes, muskegs, soil and vegetation. Probably less than 5% of the bedrock is exposed in most areas in Canada and it may be assumed that only a comparable percentage of accessible mineral deposits can be found by pick and shovel alone. The future will see increasing concentration on discovery of concealed deposits not exposed at the surface and impossible to find by the older prospecting methods. These mineral deposits will be found by systematic search using all available geological, geophysical and geochemical techniques.

During the past ten years, new geochemical techniques for finding ores have been developed and put to use; the magnetometer and electromagnetic gear are already credited with finding several important ore bodies. Given the incentive of increasing demands and markets for metals and minerals in the next 20 years, the present techniques will be greatly improved and new ones developed.

With the advent of airborne geophysical tools in particular, it has become feasible to survey large blocks of ground including drift covered areas, and to indicate small target areas where intensive search by geological, geophysical and geochemical methods should be concentrated. The application of these methods will require highly trained men and large and costly exploration programmes. The consequence will probably be a decline in the importance of the independent prospector and small syndicate; the major prospecting effort will be left in the hands of the major established mining companies, their subsidiaries, and new, adequately financed companies. They will be assisted by the basic work of government agencies and the universities.

The application of new techniques is too recent to forecast their impact on the rate of discovery of economic mineral deposits in the future with any accuracy. However, judging by the accelerated rate of discovery with the aid of these techniques in the past five years, it is reasonable to conclude that given the economic incentive of demand and markets, with attendant high prices of metals, the rate of ore discovery will remain high. Canada will maintain or better her position as a leading world supplier of mineral products.

B. Advances in Mining Practice

In the exploitation of mineral deposits, the most significant advances that have been made during recent years are in the field of mechanization. Steadily mounting costs of labour and material since World War II have hastened this trend, because at current wage rates the industry can no longer afford to pay men to do work that machines can do. To justify the higher costs of increased mechanization, the tonnage handled must be large. This has resulted in modern operations being of much greater size than formerly. Also, the mining of lower-grade ore bodies has made necessary, for economic reasons, large-scale mining operations.

In specific phases of mining practice there have been revolutionary improvements in rock drilling and blasting; the handling of broken ore; the support of mine workings; and improvements in large tonnage, non-selective mining methods. Some of these developments are discussed below.

Rock drilling is the primary operation in mining; and both the operators and the manufacturers of mining equipment are developing new techniques for increased drilling efficiency. In Canada alone the total amount of drilling comes to some 80 million feet a year, so a saving of but 1¢ a foot means a reduction in over-all mining costs of $800,000 annually. Perhaps the greatest recent advance in this field has been the development of detachable bits with tungsten carbide inserts. Their use together with improved and lighter weight rock drills has greatly reduced drilling costs by saving in manpower and increased efficiency. Multiple-mounted rock drills (Jumbos) are coming more and more into underground use because of saving in setup time, hole-to-hole time and elimination of heavy manual work. Larger rock drills have been developed for use with sectional steel in long-hole, blast-hole work. Electric rotary drills are now being used in open-pit blast-hole drilling. There have been many innovations in recent years that contribute to greater efficiency and safety in blasting operations. Some of these are: milli-second delay electric blasting caps; igniter cord; Primacord detonating fuse and short period connectors; a new blasting agent called Nitrone and small diameter powder.

Loading and transportation, both underground and in open pits and quarries, has benefited greatly by improved equipment. The development and use of mucking machines and scraping equipment for handling broken ore is growing to such an extent that it is now rarely necessary for a miner to use a hand shovel. Until recent years, shaft mucking was of necessity accomplished with hand shovels and this was the most arduous labour underground. Mechanization of shaft mucking is one of the outstanding achievements underground. The chief means of underground ore haulage is still the electric locomotive, powered by battery or trolley, but the use of diesel locomotives is growing. Trackless mining methods, in which all mining equip-

ment such as loaders, haulers, and drill rigs, is mechanized but does not travel on rails, are finding increasing use. Conveyor belt transportation of ore underground, for hoisting, and on surface is now widely used especially by mines with flat-dipping ore bodies and large outputs.

In open-pit mining the trend is toward the use of larger mechanical equipment. Diesel trucks with capacities of 22 and 34 tons are now in common use and 46-ton capacity trucks are used in some mines. The problem of introducing bigger equipment underground is not easy. Increase in equipment size is limited by the size of mine openings which in turn are governed by rock pressures and the need for their control.

Until comparatively recent years, the main methods used for ground support were timbering and backfilling with waste rock, sand or gravel. Rock bolting is now being applied extensively with considerable success in Canadian metal and coal mines, tunnels and other underground workings. Within limitations imposed by excavation widths and ground competency, rock bolting is cheaper than timbering. The use of concrete for support and reinforcement underground continues to grow. During the past 20 years, the use of hydraulic backfill using mill tailings has been growing in Canada. The most important advantage of hydraulic fill is the saving of time to backfill a working place, thus shortening the non-productive part of the cycle and increasing the output of an individual stope by 25% to 50%.

Diamond drills are used extensively in exploratory work and for finding and outlining ore bodies. The decrease in the cost of drill bits and the over-all cost of diamond drilling has made it economically practicable to delimit ore bodies well in advance of mining operations. This makes for better planned and more efficient mining operations because with detailed knowledge of the size, shape, ore grade and rock conditions well in advance of actual mining, the most economical mining method and rate of production can be chosen.

As the smaller high-grade ore bodies become less numerous, the trend is toward the mining of lower-grade large tonnage ore bodies using non-selective block caving or blast-hole stoping methods. These methods and the latter in particular, are becoming more attractive as cheaper and more efficient drilling, blasting and ore handling techniques are developed.

The trend is also toward low-cost, large tonnage, open-pit mining if at all possible. Modern large-scale equipment now makes possible the mining of ore bodies that a few years ago were considered uneconomic. Huge tonnages of overburden or rock capping can be removed economically, to expose ore deposits for mining.

The use of caving, blast-hole stoping, and open-pit mining methods greatly reduces the number of men employed per ton of ore mined. By

these methods several tens of tons of ore are mined per man-shift as compared with much less than ten tons by more selective methods. The result is a marked decrease in the labour cost per pound of metal produced. On the other hand, although the capital cost per unit of metal produced may be lower, the initial capital required in setting up large-scale, bulk mining operations is far greater because: a large ore reserve must first be assured to justify the large capital investment; and a large investment in machinery and preliminary development work is necessary to get the operation started.

Because of the large capital investment required to get such low-grade, large tonnage operations under way it is likely that these developments will continue to be controlled by a relatively few large companies that have the necessary capital (or by reputation can attract the necessary public participation) and experience to develop them and bring them to production. In this respect, Canada with a number of experienced, aggressive and wealthy mining companies (including those controlled by United States parent companies) has a considerable advantage over many other countries that may also have potential ore reserves but not the means to exploit them.

C. Improvements in Extractive Processes

Concentration and extraction follow mining of the ore. These are fields of research presenting a constant challenge to the metallurgist to find ways of treating economically the low-grade and more refractory ores. As the prospector seeks ore bodies, so does the metallurgist, by his research, prospect in the laboratory to find means of reaping the maximum return from the nation's mineral resources.

In treatment studies of ores the trend is toward a more scientific approach compared with the empirical methods of the past. Before experimental extraction treatments of ore are attempted preliminary studies are made, including mineragraphic study of the ore to find of which minerals it is composed and their mode of occurrence; analysis and assay to find out all the constituents present including those of economic value; and use of X-ray diffraction analysis for identifying minerals that occur in very small amounts and cannot be identified by mineragraphic studies. From these studies much is learned of the best method for concentrating the ores and extracting the valuable metals.

In the initial concentration or beneficiation of ores to separate and discard worthless fractions, innovations in old techniques are still being made and doubtless will continue to be made. Thus, gravity concentration is one of the oldest methods in present day use but new and improved mechanical gravity concentrators continue to be designed to cut down the cost and increase the efficiency of the operation. Heavy media separation, an application of the gravity principle, is finding new applications as means are

developed of increasing the separation density, thus extending its use. Thirty years ago froth flotation was revolutionizing the metal industry. Today it is by far the most widely used method of beneficiation, and many ores cannot be treated profitably without it. Continuing improvement in flotation is anticipated, both by better control in present application and by extension to new separations. In flotation research modern instrumental methods are proving invaluable. Research now and in the future will probably be directed particularly to the treatment of oxidized ferrous and non-ferrous ores, and non-metallic ores. Thus much research is now under way to find an effective collector for hematite (Fe_2O_3). Doubtless the solution to this problem will evolve in time and have far reaching effects on the concentration of the earthy hematitic iron ores.

In the field of non-metallic minerals, electrostatic methods are being developed for the separation of valuable minerals from unwanted materials. The method has been successfully applied to the recovery of high purity feldspar and is proving effective also in the separation of such non-metallic minerals as fluorspar, potash minerals and mica.

New methods of concentration are developed as particular needs arise and attention and money are devoted to their solution; this will continue in the future. Thus, with the depletion of high-grade direct shipping iron ores from the Mesabi range in Minnesota, the operators were faced with the choice of abandoning their holdings or of finding a method of economically concentrating the low-grade iron ores called taconites of which there is a great reserve. The economic beneficiation of the magnetic taconites is now an accomplished fact, the higher cost of treatment being partly offset because the beneficiated product is superior both chemically and physically to the direct shipping ore and gets a premium price. Much of the taconite is non-magnetic and for this material also a process is being developed in which reducing gases are injected through the crushed ore in a cylindrical furnace. This keeps the ore in a state of agitation and suspension while the roasting proceeds. Burning carbon monoxide in the furnace gives a reducing atmosphere that changes the hematite (Fe_20_3) to magnetite (Fe_30_4) which can then be concentrated magnetically.

In the extractive processes that follow initial concentration great technologic advances have recently been made and are likely to be made in the future. In the improvement of any process the ultimate objective is to cut the cost of the final product and this is usually accomplished in modern methods by elimination of labour and material and recovery of by-products discarded by older methods.

The most marked trend of late has been a revival of interest in leaching and hydrometallurgy as contrasted with pyrometallurgical smelting processes. Thus, an elevated pressure leaching process has recently been developed and

applied to nickel sulphide concentrates. Recently, two different leaching methods have been developed and successfully applied to the Cuban lateritic nickel-cobalt ores and, as a consequence, greatly expanded production from these refractory ores may be expected in the next decade. The extraction of uranium from its ores is now done almost entirely by a leaching process, a development of the past few years. Pressure leaching has also been used to extract cobalt from cobalt concentrates. On a laboratory scale it has been shown that elemental sulphur can be obtained from pyrrhotite (magnetic iron sulphide) and synthetic rutile from ilmenite by hydrometallurgical processes; these processes may be applied commercially in the near future. Leaching may also be applied to the treatment of other non-ferrous ores, including those of copper, manganese, niobium, tantalum and the rare earths, and in the future will become of increasing importance.

As an outgrowth of the increasing application of leaching processes, ion exchange and solvent extraction are finding new applications in metallurgy and their use will continue to expand. Resins are used in ion exchange reactions, the resin abstracting the desired metals from the pregnant solution. When resin removes an ionic material such as a metal from a solution it eventually becomes exhausted. The exhausted resin containing the desired metals can be returned to its original form or regenerated by treatment with an appropriate reagent and the metals recovered from the resin in the process. Ion exchange has been used for the past few years in the metallurgy of gold to extract the gold from pregnant solutions. The technique has recently been applied to recover and concentrate uranium from leach solutions. Perhaps most spectacular is the application of ion exchange to the metallurgy of the rare earths where it makes possible the hitherto almost impossible separation of these elements.

In solvent extraction, which is coming into increasing use in metallurgy, such a solvent as ether, kerosene or other organic material is added to leach solutions from which it extracts the desired metals. The solvent, with its dissolved metal, is insoluble in the leach solution and can be separated easily. This technique has been applied on a commercial scale in separating uranium in leach solutions. It will doubtless be more widely applied in the future although its relatively high cost limits its application to the treatment of the higher-priced metals.

Many of the developments just mentioned have taken place within the past five years. They indicate the technology of metal recovery to be advancing rapidly and, given the incentive and need, new developments will continue in the future. Many of the developments in the hydrometallurgy of nickel, cobalt and copper and in such newer metals as titanium, zirconium, uranium and the rare earths have been by chemical engineers. We are witnessing the impact of such chemical engineering techniques as pressure

leaching and ion exchange on metallurgy. The chemical engineers who have brought plastics and synthetic fibres out of the laboratory and into the home have still much to offer the metallurgist. The demands for a greater variety of metals, and other products will give the chemical engineer and metallurgist opportunities for collaboration not only in research on the recovery of the minor metals but also of by-products. The full harvest of the closer association of the two professions has still to be reaped.

Improvements in methods of processing ores and concentrates permit lower-grade and highly refractory ores to be treated economically. These improvements are also directing attention to the possibility of re-treating tailings, slags and other metallurgical by-products either following or intermediate to metallurgical processes.

The magnetic separation and flotation of bessemer copper-nickel matte is an example of what can be done in beneficiating a metallurgical product.[b] This has recently replaced the old and complicated top and bottom smelting process which depended on the separation in a molten state of liquid layers of nickel sulphide and copper sulphide. By the new process the molten copper-nickel bessemer matte is cooled under controlled conditions, crushed, ground and subjected to magnetic separation and flotation to yield a magnetic concentrate rich in precious metals; nickel sulphide concentrate; and copper sulphide concentrate.

The recovery of the iron content (and eventually the sulphur) of nickel-bearing iron sulphide is an example of the recovery of by-products hitherto discarded. In this recently developed process the nickel-bearing iron sulphide is subjected to fluidized bed roasting, kiln reduction and ammonia leaching. The nickel is recovered as nickel carbonate and the remaining fine iron, after agglomeration, is marketed as high-grade open-hearth feed. The sulphur will also eventually be recovered although this is not being done at present. Somewhat similar methods are presently being developed and applied to the recovery of the iron and sulphur from several other base metal sulphide deposits in Canada.

The future will see increasing attention to re-treatment of tailings and other waste products which in many cases contain metals and other elements that were uneconomic to win with the processes and markets available at the time they were milled. For example, the sulphides in the tailings from the lead-zinc ores of the Sullivan mine at Kimberley, contain large amounts of recoverable iron and sulphur that will doubtless be reclaimed in the near future. Likewise, the great tailing dumps from the asbestos mines in the Eastern Townships of Quebec form a large reserve of nickel, iron, chromium and magnesium that are, at present, entirely uneconomic to recover; but

b *The Nickel Industry in Canada*, a presentation to the Royal Commission on Canada's Economic Prospects, January, 1956.

further developments in metallurgy and chemistry and the possibility in the future of plentiful and low-cost nuclear power may eventually make them of economic interest.

The lateritic nickel-cobalt-iron-chromium ores of Cuba constitute the largest known nickel reserves in the world. They are an example of ores with a high gross value of salable metals so refractory to treat, that until recently, their exploitation has been uneconomic. A United States government plant began production of nickel from the Cuban laterites in 1943, was closed in 1947 and reopened in 1952. It is reported that nickel is being produced at this plant at a cost, including plant depreciation, below the current market price of nickel.[3] The Freeport Sulphur Company, using a different leaching process that gives a higher recovery of nickel, is reported to plan production of both nickel and cobalt from the Cuban laterites by 1959. Research continues to develop economic methods for the recovery of the iron (about 49%) and the chromium (about 3%) that these ores contain in addition to the nickel and cobalt. An economic process to recover these metals seems capable of development; if this process as eventually developed were to involve the use of much electric power the ores might be treated at Canadian ports as bauxite and alumina are.

By far the greatest amount of iron ore is reduced to metallic iron in the blast furnace. Where there is a large demand for iron this is, and will continue to be, the cheapest process in the foreseeable future. The trend has been to larger and larger blast furnaces; new ones being built are generally capable of producing 1,000 tons or more of pig iron a day. The largest furnaces are having difficulty with cones of frozen metal forming at the centre of the stacks because the blast is not reaching that zone; redesign of furnaces will be necessary if larger diameter units are to be built. Oval or rectangular cross-section furnaces have been proposed to eliminate this dead centre but, as yet, have not been constructed.

Because of the high stack (100 feet or more) in the blast furnace the coke must be very strong to support the charge and hence a high-grade coke is essential. As reserves of the better coking coals are depleted, lower quality coke must be used. The development of a low shaft, oval shaped blast furnace may make this possible.

In such areas as the west coast of Canada where electric power is plentiful and only a limited market for steel exists, electric smelting may be economically feasible. The initial capital outlay for an electric smelting furnace is not as great as for a blast furnace and a large variety of ores can be processed. There has been no radical change in the electric reduction furnace since its invention more than 50 years ago and though it is effective it is not particularly efficient. A more efficient electric furnace could strengthen

Canada's position not only in the iron and steel industry but in a wide range of electrometallurgical processes.

Direct iron ore smelting processes involve reduction of the iron ore to produce metallic iron at a temperature below the melting point of the ore or iron. The resulting product, which is known as sponge iron, is light and porous; it can be used instead of steel scrap in a furnace charge. There are a number of such direct smelting processes; and in one of them, steel strip is produced directly from the ore. In this process, which was developed in Canada, a thin layer of iron ore is conveyed through a hot reducing atmosphere to produce a continuous strip of low density steel. This strip is then hot rolled while still in the reducing atmosphere to produce normal density steel. Cold rolling and annealing follows and the resulting product is claimed to have similar properties to steel produced in the conventional way.

D. New and Substitute Materials

(a) *Competition and Substitution*

Based on abundance and availability of their ores the common metals may be divided into two groups. The first group consists of metals of practically unlimited supply and includes iron, aluminum, magnesium, titanium and some of the less common metals. High-grade ore reserves of these metals are sufficient for many decades even at greatly increased consumption rates. Lower-grade ore reserves are practically inexhaustible.

The second group consists of metals of limited supply. It includes all the heavy non-ferrous metals such as copper, lead, nickel, tin, zinc and a number of less common metals. High-grade ore reserves of these metals are limited; even at present rates of consumption, low-grade ores are being exploited to meet the demand, and the trend toward mining still lower grades will continue. This will tend to increase the mining and extraction costs and, consequently, the price of these metals. The increased price in turn will tend to lower their consumption in many applications where metals of the first group may be substituted.

A further difference in the two groups of metals is the relative stability of prices of metals of the first group compared with the second. This is caused by their geographical distribution and the contrasting industrial structure of the companies that mine and produce them. Thus ore reserves of the heavy non-ferrous metals (second group) are concentrated in comparatively few areas of the world, and often in remote and undeveloped countries. As a consequence, supply and prices are influenced not only by demand but by such unpredictable factors in the countries in which they are mined as labour disputes, political unrest and taxation policies. An example is the recent short supply and consequent high price of copper caused in part by

increase in consumption in Western Europe but mainly by labour disputes in Chile, one of the world's largest copper producing countries. On the other hand, raw materials for the ferrous and light metals are distributed more uniformly and are easily accessible in many places in the world. It is true that aluminum production is dependent on cheap power but the importance of hydro power should not be overstressed because several economically competitive aluminum producing plants are based on electrical power generated from natural gas (United States), coal (Germany, United Kingdom) or lignite (United States); and perhaps in the not too distant future the aluminum industry may use nuclear power that will be independent of geographical limitation of fuel or water supply.

The contrast in the industrial structure of the companies producing and fabricating these two groups of common metals is striking. The ferrous and light metal industries are highly integrated industries that include most or all phases of metal production from mine, through refining, ingot making, metal forming operations even to the manufactured product. The heavy non-ferrous metals (except nickel) have, in most cases, separate and only remotely connected industries; the mining, refining, ingot making and manufacturing tend to be independent of each other. The aluminum and magnesium industries are examples of the first group. Aluminium Ltd., ALCOA, Kaiser, Reynolds, the French Pechiney group and others have fully integrated production from bauxite ore to aluminum foil, die castings and various fabricated products; Dow or Domal handle magnesium from seawater and dolomite, respectively, to magnesium ladders and jet engine castings. The copper industry is an example of the second group in which the production is divided into a considerable number of separate and mostly independent industries devoted to mining, refining, ingot making, brass mills, wire mills, foundries, etc. The fully integrated industries have the advantage of a greater stability in price structure.

Future long-range industrial growth will be based to an increasing degree on further technological development in the ferrous and light metals rather than the heavy non-ferrous metals because of their greater abundance, world-wide distribution and availability, and, in lesser degree, to their more stable industrial organization and price structure. This does not mean any marked decrease in the importance of the heavy non-ferrous metals in the future or that, for at least a few decades, their rate of consumption will decrease. But the heavy metals will not be available in all their present fields of application in the quantities and at competitive prices necessary for the greatly expanded needs of the future. In the past, and in many cases today, these metals have been used not because of their technical superiority, but because they were cheaper or because of unwillingness to use newer and less tried materials.

In the future the base metals will be used only in applications where their

properties and service characteristics make them irreplaceable, or at least technically superior.

The replacement of copper by aluminum is a good example. The trend to replace copper by aluminum in various electrical applications has become desirable partly because aluminum is superior in certain applications but mainly because of the higher cost of copper which, although aggravated by other factors, is basically due to depletion of high-grade copper ore reserves. It has been predicted that the annual electric power output in the United States will rise from the present (1954) 470 billion k.w.h. to an estimated 1,400 billion k.w.h. in 1975. The consumption of this large increase in electrical power will require a similar increase in materials for electrical transmission, busbars, distribution lines, building wire, motor windings and many more products. Copper production cannot be increased to take care of these and many other demands, without resort to marginal producers and resulting high-cost copper. Aluminum, as a consequence, is taking over and will continue to take over a larger and larger share of copper's market. The same is true of tin and a similar, although less marked, trend is apparent in the case of zinc and lead. World production estimates for 1955 show that the primary aluminum tonnage exceeded, for the first time, the production rate of any other non-ferrous metal; this trend will continue.

Another important factor in the trend toward further development and use of the light metals, is the rapid progress being made in fabricating techniques and their adaptation to mass production; by the demand for high speeds in transportation; and by their relative stable prices. Light metals are replacing other materials in many applications where they are better fitted for the particular service conditions and where hitherto only a higher price has prevented their use. Expansion in their use will continue to be based on new fields of application, made possible by their valuable properties as well as their abundant potential supply.

Competition of the light metals with steel is limited. The physical, mechanical and especially the chemical properties of ordinary steel are seldom superior to those of its non-ferrous competitors; but wherever high quality or low weight are not essential, the low price of steel precludes serious competition. The entire world production of light metals (Al and Mg) in 1954 was 3.1 million short tons or only 1.26% of the 1954 world steel production; thus any substitution or significant competition of the light metals with steel is on a small scale. Nor will this be likely to change greatly in the future. Aluminum and perhaps also magnesium will make further small inroads into fields considered traditionally ferrous, and with a large decrease in price, titanium may become competitive with stainless steel, but these gains are unlikely to exceed 2% or 3% of total steel production in the foreseeable future.

Competition is also developing among metals and such non-metallic materials as plastics, vulcanized fibre, synthetic rubber, glass, plywood and specially treated wood, and structural ceramics. Plastic surface coverings, wall coverings, floor tiles, and counter tops have won acceptance for their durability and attractive colours. Plastic screening is widely used. In the construction industry, transluscent glass fibre surfaced plastic panels are used for interior partitions, luminous ceilings, etc., and transluscent plastic foam between transluscent plastic sheets transmits light and provides insulation. Wood-faced panels with fillings of plastic foam have been developed for housing and the future will see development of panels faced with hard surfaced, weather resistant, exterior surfaces. Already, to a large degree, asbestos panels have replaced galvanized iron for both interior and exterior surfaces. More rapid expansion of plastics in housing and construction is hindered by their cost, which is considerably higher per pound than steel, and by hesitation on the part of consumers to accept materials that have not been tested by long use.

Plastic and asbestos cement pipes are being widely used in place of iron, steel and copper. Lightweight concrete made with such lightweight aggregates as those made by bloating shales are coming into wider use with consequent saving in the amount of structural steel needed for support. Refractory ceramics are being developed to coat metals which must resist high temperatures as in jet engines, thus increasing their efficiency and life.

However, although non-metallic materials have excellent properties and are keenly competitive in particular applications, they are not serious competitors in the more general applications that constitute the major markets for the metals, nor are they likely to be in the foreseeable future.

(b) *Trends in Industrial Alloys*

A survey of properties of metals and alloys, used as engineering materials, shows there are no all-purpose materials; each metal has its field of application where a combination of physical, mechanical and chemical characteristics makes it superior to any other material. Because in many cases the basic price of the material used is but a small percentage of the manufacturing costs of the product, there is a strong tendency to base selection of metals more on their engineering qualities than price alone.

The modern trend in industrial product design is to develop special or custom made materials for specific service conditions. Thus the rapid progress in larger and faster aircraft, both piloted and pilotless, has required the discovery of alloys having the highest possible strength-to-weight ratio at temperatures encountered under actual service conditions, and various nickel, cobalt, titanium, iron, aluminum and magnesium-base alloys were developed for this purpose and others are being sought. Other examples of

this trend are special alloys developed for various services in electrical applications, electronics, heat transfer and the chemical industries.

The advent of the gas turbine engine has greatly accelerated the search for better and cheaper high temperature alloys. The so-called super alloys for service under stress at temperatures over 800° C (1,470° F) may contain up to 60% cobalt, although such alloys are now being replaced by some requiring much less or no cobalt and from 60% to 70% nickel. These alloys also contain about 20% chromium and from 1% to 5% niobium, molybdenum, titanium, and aluminum. Significant quantities of these alloys are used for gas turbine engine blades.

For service under stress at temperatures between 550° to 800° C (1,000° to 1,475° F) the high temperature alloys usually contain about 50% iron with some nickel and cobalt, about 20% chromium and usually only aluminum and titanium as hardeners. In order to further conserve nickel and cobalt a series of ferritic high temperature alloys have been developed which are used in disc forgings for gas turbine engines and other applications where temperatures do not exceed 700° C (1,300° F). These alloys require several per cent niobium or molybdenum.

A greatly expanded jet engine building programme could require quantities of nickel and cobalt that might strain currently available supplies. However, the substitution of guided missiles for manned aircraft will reduce considerably the number of jet engines to be built for military purposes. The development of the industrial gas turbine for use in automotive transportation could create a market for large quantities of nickel and possibly cobalt. However, the progress of this development is uncertain, and is more likely to be restrained by economic considerations than by any lack of nickel or cobalt.

Another important trend is the increasing demand for highest-purity metals and, recently, highest-purity alloys. Requirements for materials for nuclear power installations have greatly accelerated research on various purification methods and methods for the detection of minute impurities, and made the metallurgist and the materials engineer purity-conscious. The effect of small amounts of impurities in zinc has been known for some 30 years and the development of commercial high-purity zinc (99.99% minimum) was the foundation of the modern zinc die casting industry. This industry in 1955 consumed in the United States 410,000 short tons of special high-grade zinc and is still growing.

A similar trend is likely to develop in the aluminum industry. High-purity aluminum (99.99% minimum) has been produced commercially in Europe for some 30 years, and the effect of high-purity on the properties of aluminum products (reflectivity, electrical and thermal characteristics, duc-

tility, high corrosion resistance, etc.) has been known. But it is only recently that American industry has started to introduce on a large scale high-purity aluminum in various electrical applications, collapsible tubes, foil, cable sheathing, reflectors, etc.

Canada produces commercially, without additional cost of refining, a high-purity grade of magnesium (99.98%). This product has advantages in use for special aircraft products and in the production of titanium by the Kroll method.

Other examples of uses of high-purity metals for special applications might be mentioned for germanium, silicon, lead, calcium, bismuth, indium, etc.

The most recent development of aluminum alloys for critical applications is based on the use of high-purity metals in the production of castings. Much better mechanical properties and increased ductility can be obtained by elimination of various impurities, considered hitherto as harmless or even beneficial. Further research along these lines seems promising.

Another interesting recent development is the possibility of producing synthetic alloys by powder metallurgy. Considerable success has been achieved in producing sintered aluminum powder products (SAP) which exhibit high room-temperature strength retained at elevated temperatures (up to 450° C), high creep resistance and elevated temperature fatigue properties, good corrosion resistance and thermal and electrical properties similar to pure aluminum. These products can be produced as extrusions, sheets or forgings, and are of great interest for various elevated temperature applications in aircraft and engine components (e.g. pistons). Similar development work on sintered magnesium alloy powder products indicates promising possibilities in elevated temperature applications and in the production of alloys that contain elements that could not be retained in the molten metal, e.g. the addition of aluminum to magnesium-zirconium alloys.

The most important trend in modern industrial development is that toward automation; that is, continuous fabricating processes and the introduction of labour-saving handling methods and equipment. Although in most industries this goal is still far away, a growing number of continuous casting and continuous rolling installations, as well as many more or less automatic machines, are already common equipment in larger industrial establishments. Another trend is toward the development of processes capable of producing large forgings, castings or sheet formings to replace complicated structural components formerly assembled from numerous parts or machined from bulky billets, thus saving costly machining or assembly man-hours. Continuous processes combining casting and metal forming are gaining importance and considerably increasing productive efficiency.

(c) *The Newer Metals*

Several metals with ores in abundant supply are used in only minor amounts. Some have properties that make them of limited use; others possess unique and valuable properties; they await development of processes for economic extraction of the metals from their ores and recognition by industry and the consumer of the uses to which they may be put. Until the last decade, aluminum fell into the latter category; now, after many years, its valuable qualities have been recognized and it is making, and will continue to make, inroads in fields previously monopolized by other metals. Uranium and its nuclear derivative plutonium is another example of a metal of little use to man but a few years ago. In the next five years it will probably take a foremost place in dollar value among metals produced in Canada.

Among the metals with valuable properties with ores in abundant and widespread supply, but used as yet in minor degree, are magnesium and titanium; these are discussed in a previous chapter. Other metals in large potential supply, but with properties that at present limit their usefulness, are silicon and calcium. In less abundant potential supply, but with valuable properties that may lead to much greater use in the future, are zirconium, lithium and the rare earths. These potentially important metals are discussed in this section.

(i) *Calcium*

Calcium, an alkaline earth metal, is the fifth most abundant element in the earth's crust. In spite of excellent workability and lightness it is not widely used because of poor corrosion resistance. Its principal uses are as an alloying agent in aluminum, magnesium, and lead-base bearing alloys; a reducing agent for beryllium; an alloying agent and deoxidizer for copper; in age-hardenable lead alloys for cable sheathing, battery plates, etc.; for removing the bismuth from lead; a desulphurizer and deoxidizer for various alloys of nickel, copper, chromium, and steel; and as a reducing agent in the production of thorium, uranium and zirconium.

Calcium metal is produced in Canada by thermal reduction of lime by Dominion Magnesium Limited, Haley, Ontario, which is the world's largest producer. The annual production for 1948 was reported as 450 short tons; later figures have not been published.

Much more research is necessary if the uses of this metal, whose ores are in such abundant supply, are to be increased.

(ii) *Lithium*

Lithium is one of the most versatile elements used in modern technology. Canadian lithium ore reserves are substantial and the development of further uses is therefore of particular interest. In 1955 Canada became, for the first

time, an important producer of lithia concentrates from the Lacorne Mine, Quebec.

Lithium is the lightest metal known. It is silvery white in colour, soft, malleable and ductile, and has the highest specific heat of any solid element. It reacts readily with the atmosphere and therefore cannot be used unless protected by an inert atmosphere or cladding. The principal uses of lithium at present are as lithium stearate in lubricating greases which have exceptional water resisting properties and efficient service properties at temperatures ranging from —50° C. to +50° C.; in air conditioning units to control humidity; in alkaline storage batteries; and in pharmaceuticals. Metallurgical applications include the use of lithium as a degassing and deoxidizing agent in various non-ferrous metals and alloys; in welding and brazing flux; in heat treating atmospheres; and as an alloying addition to lead-base bearing alloys.

Further research on magnesium-lithium alloys is of particular interest because, if present difficulties due to age-softening of these alloys can be overcome, they would revolutionize the whole field of wrought magnesium alloys. Experimental magnesium-lithium alloys show strength-to-weight ratios 50% higher than those of the strongest aluminum alloys.

Lithium can be used as a heat transfer agent in atomic reactors if its corrosive nature can be overcome. Lithium could be used also as a propellent in rockets because under certain conditions the metal oxidizes readily with large release of heat.

Lithium forms a hydride with hydrogen, and with deuterium (heavy hydrogen) forms lithium deuteride. This compound has a high neutron capture and could be used as shielding for fusion reactors. Theoretically, lithium deuteride can be utilized in the nuclear fusion reaction because when lithium is bombarded with neutrons, it yields helium with consequent release of enormous amounts of energy in the form of heat and radiation. If this reaction can be controlled it would be a source of almost unlimited power.

(iii) *The rare earths*

The rare earths are a group of some 16 metals (cerium, lanthanum, etc.) that are generally associated in nature. Their melting points range from 812° to 1,500° C., their hardness from that of lead to that of steel and their density from three to eight. In the upper lithosphere the rare earths are not very rare; their combined abundance in the earth's crust surpasses that of copper or nickel. The term rare earths is a misnomer applied when it was thought that these metals were widely dispersed and rarely concentrated. Recent search has shown that they are concentrated in places in large deposits.

The rare earths are obtained mainly from monazite concentrates from beach sands in Brazil, India and the United States and from bastanaesite from a body of carbonate rock in the United States. In Canada rare earths are associated with the uranium ores of the Bancroft and Blind River areas and niobium deposits near Oka, Quebec, and North Bay, but there has been no commercial production.

The rare earths have been used mainly in lighter flints, tracer bullets, etc. because of their pyrophoric nature; and in the glass industry. Recently, however, they have been used in making both ferrous and non-ferrous alloys and in the future may become of great importance in this field. In plain and low alloy steels the addition of rare earths raises the impact strength, and in high alloy and stainless steels results in better ingot structure improving the hot workability. Rare earth additions to magnesium alloys improve their properties at elevated temperatures and the pressure tightness of castings; additions to aluminum alloys also improve their properties at high temperatures; and in nickel alloys rare earth metals improve their resistance to oxidation at high temperatures.

Considerable research is under way on the separation of the rare earth metals and to learn more about their properties and potential uses.

(iv) *Silicon*

Silicon is the second most abundant element in the earth's crust. In the pure state it is 14% lighter than aluminum and yet has a melting point only slightly lower than iron; it has excellent resistance to corrosion and oxidation at high temperatures and is unattacked by salt solutions and many acids. However, silicon is too brittle to be formed into shapes and cannot withstand impact as other metals do.

The main use of silicon is in the field of ferrous metallurgy in the form of ferrosilicon. High-purity (over 99.9999%) silicon metal is available at a considerable price and is used principally in the electronics industry in rectifiers and transistors. Such devices produced from silicon can operate at higher temperatures than those produced from germanium. Another potentially important application is siliconizing, that is, formation of a protective coating by depositing silicon in a replacement reaction on steel, molybdenum, tungsten, tantalum, etc. Silicon coated molybdenum products would be particularly attractive for use at high temperatures, utilizing the excellent high temperature strength of molybdenum protected by the heat and corrosion resistant silicon coating. Other uses of silicon include its use as an alloying addition to aluminum alloys to increase strength and castability; to copper-silicon alloys (silicon bronzes), which were introduced during World War II to replace tin bronzes and have high strength and excellent welding properties; to silicon brasses to increase strength; to nickel alloy, etc. In the non-

metallic field the development of silicones created a large field of new materials. Considering the plentiful supply and its many useful properties, the use of silicon and its compounds will undoubtedly grow.

(v) *Zirconium*

The main commercial source mineral of zirconium is zircon, which is obtained from beach sands and river gravels in the United States, Australia, Brazil, French West Africa and India. In common with ores of the light metals, reserves are large and exceed the foreseeable demand for the next 100 years or more. No commercial deposits of zircon are known in Canada.

The present chief use of zirconium metal is in nuclear energy plants, particularly in power reactors operating at high temperature. Zirconium and certain of its alloys have high permeability to slow neutrons and also high corrosion resistance. This metal may ultimately lead all others as a sheathing material for nuclear fuel elements.

Zirconium is the equal of tantalum in resistance to hot acids and also resists many alkalis which tantalum and niobium cannot do. It is also cheaper and lighter in weight than niobium and tantalum and can replace either in most uses. That it has not done so is due to heavy demand for it by the atomic energy industry.

Zirconium is also important as an alloying element in cast and wrought magnesium alloys of high strength-to-weight ratio at both room (Mg-Zn-Zr alloys) and elevated temperatures (Mg-rare earths-Zr and Mg-Th-Zr alloys). Both types are being used increasingly in modern aircraft and airborne equipment. Zirconium is also used as a grain refiner in aluminum alloys.

Production techniques have been developed to yield a ductile and easily handled metal. Reduction in the price of zirconium sponge from its present price (about $10.00 a lb.) to $2.00 a pound would result in greatly increased consumption of the metal. It has many chemical similarities to titanium and is produced by a similar process. As further economies in titanium production are developed they will be applied to zirconium.

E. Conclusion

The technological advances at hand and in the offing promise adequate supplies of the metals and industrial minerals so essential to raise the world's material standard of living. New techniques for the discovery of ore deposits promise to maintain adequate reserves. Improvement in mining methods and the metallurgical treatment of ores promise to make economic many ore bodies too low in grade or refractory to exploit in the past. The light and ferrous metals, which occur abundantly in nature are supplanting others which are in much more limited supply. This makes possible the restriction

of the heavy base metals to fields in which they are irreplaceable or technically superior.

Further mechanization and the use of caving, blast-hole stoping and open-cut mining means greatly increased output per man and the replacement of manpower by machines. Similarly, in the treatment of ores the trend is toward continuous flow processes which lend themselves to automation and curtailment of labour. Consequently, increase in volume of metals and minerals produced in Canada in the future will not see a corresponding increase in employment of labour in the mining and mineral processing industries.

The use of modern geophysical and geochemical techniques requires highly trained men and involves large and costly exploration programmes. In addition, modern large tonnage mining operations require heavy capital investment in machinery and preliminary development work. Consequently, the large capital investment necessary for the discovery, development and mining of the ore bodies of the future will probably mean an increasing concentration of control in the hands of relatively few large companies. This does not mean that successful new mining companies financed by public participation will not continue to develop and grow. In the prospecting and exploration stages in particular, small groups can accomplish much because they possess initiative and can pursue policies not always open to large corporations. But the heavy investment needed to prepare a property for large-scale production tends more and more to be supplied by the established mining companies that have the necessary capital, or by their reputation can attract the necessary public participation to bring a new mine to production. Canada, with a number of established, experienced, aggressive, and wealthy mining companies (including those controlled by United States and, more recently, by British and European parent companies) and a stable political and economic environment, has an advantage over many other countries with large potential ore reserves but not the means to find, develop and bring their prospective mines to production.

To ensure the continued growth and prosperity of the mineral industry Canada must retain her lead in technology among the other nations of the world. Canada has no monopoly on the world's mineral deposits; other nations and continents, notably Asia, Africa, and South America, have potential mineral resources comparable with our own. If we are to maintain our present position we must foster research, both fundamental and applied, that will keep Canada in the forefront in the development of geological and geophysical techniques for finding new deposits and in the development of improved metallurgical processes for the recovery of the valuable materials they contain. Such research cannot be carried on without the right men to inspire and direct it. These men are, and may continue to be, in short supply.

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8

THE ROLE OF MINERALS IN THE CANADIAN ECONOMY

A. General

The character and extent of economic development in any country is greatly influenced by the quality of its natural resources and the manner in which they are exploited. Among them, minerals occupy an important position. Not only do they provide the raw materials essential to support the nation's own metallurgical, chemical, engineering and construction industries but, through international trade, they frequently earn amounts of foreign exchange without which the importation of up-to-date equipment, suitable manufacturing processes and operating techniques would be slowed down, if not entirely inhibited.

One of the more measurable effects is employment. Yet this, together with the opportunity for local labour to learn new skills, is less than formerly. Open-pit mining and similarly mechanized operations underground have so reduced the number of on-site workers that major resources can be developed with the aid of much less labour than was the case even a decade ago.

Meanwhile each new project creates a demand for various goods and services. Much of the construction is local in character. Nearby sources of building materials are preferred. Such ancillary services as airports, roads, railways and electric power and water facilities, facilities which can also be used for purposes other than mining, frequently have to be created. Secondary industry within the country may also benefit to the extent that it is supplying some part of the capital goods required for these purposes.

In instances where initial processing is also undertaken, these effects are multiplied, often two or threefold. The smelting and refining of most metals usually provides work for a labour force at least as great as that employed in the mines and in the ore concentrating plants. Maintenance, too, is a large item of cost. Material inputs, especially those of a chemical or metallurgical variety, demand a host of manufactured goods from other industries. Frequently by-products are also generated. These, in turn, may form the

basis for still other types of industrial development. This combined demand calls for even greater support from the service sector. Power is no longer required in hundreds, but in tens of thousands of horsepower. Thus, directly and indirectly, measures aimed at the further processing of Canadian mineral resources can and frequently do have a much greater effect upon the economy of a region than such simple measures as direct employment would otherwise indicate.

Table 35, listing representative prices of certain raw metals in the raw ore and refined form, gives further illustration of what this multiplying effect may be.

Table 35

REPRESENTATIVE PRICE OF METALS AT DIFFERENT STAGES OF PROCESSING[a], MAY, 1957

Metal	A Metal in ore or concentrate (estimated price/lb.) metal content	B Metal as a refined product (price/lb.)	Ratio B/A
Aluminum	1.3¢ (metal in bauxite)	24.5¢ (aluminum ingot)	19.0
Cobalt	70¢ (cobalt conc. 11% grade)	$2.00 (cobalt metal)	2.85
Copper	24.0¢ (copper conc. 22% grade)	30.75¢ (refined copper)	1.28
Iron	1.0¢ (iron ore 51.5% grade)	3.25¢ (pig iron)	3.25
Lead	10.8¢ (lead conc.)	15.5¢ (refined lead)	1.42
Lithium	$1.26 (spodumene conc. 6% grade)	$12.50 (lithium metal)	10.0
Magnesium	7.0¢ (metal in magnesite)	33.5¢ (magnesium ingot)	4.8
Nickel	24.0¢ (nickel conc.)	70.0¢ (electrolytic nickel)	2.9
Sodium	2.7¢ (refined NaCl)	17¢ (sodium metal)	6.3
Titanium	3.53¢ (Indian ilmenite conc. 60% grade)	$2.75 (titanium sponge)	78.0
	15.5¢ (rutile conc.)	$2.75 (titanium sponge)	17.7
Uranium	$7.27 ($U_3O_8$ conc. 0.5% grade)	$18.18 (uranium metal)	2.5
Zinc	5.8¢ (zinc conc.)	13.5¢ (Prime Western zinc)	2.32

a See also *Non-Ferrous Metals in Underdeveloped Countries*, United Nations, New York, 1956.

In Canada, as with many other comparatively undeveloped countries, most of the nation's mineral output is exported. Sold elsewhere, it earns an income in terms of foreign exchange, some of which goes for the payment of dividends to non-residents and for the purchase of still more foreign-built mining machinery and equipment. Yet, if the enterprise in question is eco-

nomically sound, it also does more than this. It provides public revenue and hence helps to support other and quite different types of activity which may range from school building to old age pensions, and from highway construction to defence.

Maximization of these developmental effects usually requires that the industry be treated as an integral part of the economy within which it operates. Thus the profitability of a given mine or even the gross earnings accruing from the sale of minerals abroad, though significant measures of economic well-being, are not the only criteria of benefit or, for that matter, the most pertinent ones. For example, were a steady rise in the price of a given mineral to be in prospect or, alternatively, if the mineral were to be underpriced in long-term contracts to a parent corporation abroad, over-rapid exploitation might well be inimical to the best interests of Canada.

An accelerated defence programme, especially in the more highly industrialized countries—if it were not accompanied by an appropriate increase in price—might also, through high grading, unduly hasten the depletion of resources. Neither, in some instances, does it pay to sit and wait. Thus the buying up of large tracts of favourable mineral-bearing territory by some of the larger internationally controlled companies, whose concern about their long-term future supply position elsewhere leads them to make such investments, may also, through delay and as a result of a stable or relative decline in price, reduce the economic return which might otherwise accrue to the mining region in question.

One of the characteristics of the modern mineral industry is its concentration, at least that of the larger and more productive properties, in comparatively few hands. International connections and especially assured markets with parent or associated companies engaged in further processing in the more highly industrialized countries, as we have seen, are useful, if not altogether necessary conditions to survival. A new mine may take a long time to become productive. Prices, meanwhile, may change. For these reasons it may prove mutually beneficial to have exploration, mining development and primary processing financed by outside capital whose relations with foreign governments and whose connections with manufacturing industries in the more highly industrialized communities are likely to stand the test of time. Meanwhile, the limited funds available to the resource country can be better applied to those many other areas of social and commercial activity which, at least in the early stages of economic growth, are likely to be both more urgent and less likely to suffer disappointment.

In the majority of cases, the purpose of these investments is to produce minerals for sale elsewhere. Yet by no means all of the output is sold on a spot basis to the highest bidder. On the contrary, many new mines are being opened up to supply part or all of the raw materials intake of a particular

smelter, refinery or other processing plant in the more highly industrialized consuming region. Well defined relationships can often be traced between individual mines and certain further processing and fabricating plants elsewhere. Corporate relationships of this kind, while they impart an element of rigidity into the nation's mineral trade, have the advantage of ensuring to Canada a sizable share of the country's export market in both good times and bad. They invite criticism in that there is no clearly established mechanism for price determination. Whether the yield to the country of origin is appropriate or not is left largely to the reasonableness of the parent company's top level executives and cost accountants. Thus the virtual disappearance in the case of a number of minerals of a comparatively free market has rendered difficult a proper determination of the true advantage of the mineral producing country whose major preoccupation is that of supplying raw and semi-processed minerals to other countries through intra-company channels, where the true forces of supply and demand are frequently obscured by other considerations.

This highlights one of the difficulties of preparing value forecasts. Were the great bulk of Canadian mineral production to be exported in the form of ores and concentrates, one set of dollar figures would obtain. Were it, on the other hand, to be processed in its entirety to the metal or more universally usable stage, the gross value figures could be doubled or trebled. Granted, smelting, refining and other types of primary manufacture also have a high import content. However, there can be little doubt that decisions aimed at protecting the raw material supply position of primary industries or designed to facilitate their expansion elsewhere could be and in a number of instances might well be, detrimental to the long-term economic interests of resource producing countries like Canada.

Up to a point, the higher the wage level and the more labour-intensive the process of mining and primary manufacture, the more favourable are the local effects. Productivity has, of course, to be taken into account. The ultimate potential of a mine depends essentially upon how much material can be classified as ore. Higher wages, to the extent that they result in higher working costs, reduce the incentive to work lower-grade material. Thus the economic extent, and hence the amount of resource itself, may be limited. In respect to open-pit and other highly mechanized operations the situation may not be altered to the same extent. In such instances an increase in the wage bill is less likely to affect over-all costs, working practices and the mine's ultimate potential. If anything, its result is more likely to be a modest decline in profits, some of which is reflected in turn in lower government revenues and smaller dividend payments to shareholders.

The higher the domestic content as measured in purchases of materials, equipment, operating supplies and services, the greater is the contribution to the local economy. Yet, under modern circumstances, this, if confined

simply to mining, may be limited. Although nearby farms, stores and repair shops will have an advantage which flows from their proximity to the mining community, their market is often too small or their resources too limited to sustain much secondary manufacturing. Such concerns as do attempt to supply capital equipment usually find themselves face to face with competition from well-known and much better established producers in the more highly developed parts of the country or abroad. In Canada, as in other source countries, most types of mining equipment and supplies are admitted duty-free or nearly so. These decisions have been based on the belief that while higher tariffs may encourage some types of manufacture, they will also add to costs and hence hurt the competitive position of the nation's mining and mineral processing industries in world markets. This view is well founded. Yet, in practice it has limited the markets available to manufacturers in this country. Only to the extent that a few processed materials like the bulkier chemicals are required in the treatment of these materials is the incentive to further growth through manufacturing given an appreciable momentum by developments of this kind.

Revenue produced by these industries often takes the form of foreign currency earnings. A portion is used for the purchase of foreign made machinery and equipment, the importation of processed materials not manufactured in Canada, the maintenance of head offices, engineering facilities and market research facilities located abroad, and for the payment of interest and dividends to debenture and shareholders normally resident outside the country. The rest of these foreign exchange earnings are converted to Canadian dollars which, added to those resulting from domestic sales, can be employed in meeting local expenses including the payment of taxes. The actual distribution of mine revenue among these various recipients depends, of course, on the volume of mineral produced, the price which it realizes in international trade and the policy followed by various levels of government regarding such matters as exchange control, royalties, land taxes and income taxation.

As far as methods of collection are concerned, the influence of a given tax upon the development potential of the mining industry has a fairly determinant effect. A royalty payable on the volume of ore removed, for example, is likely to discourage the extraction of low-grade material; an export tax on concentrates seems calculated to encourage a greater measure of domestic smelting and refining; an obligation placed on mining companies to hand over the export proceeds in the form of foreign exchange of its local costs at an unfavourable exchange rate is likely to curb further investment; allowances on mining income which permit a rapid writing-down of capital expenditure tend to do the opposite—namely, to encourage further expansion. The tax most commonly employed (and certainly the largest in money terms) is one on profit. This is less onerous in that it offers the fewest impediments

to private investment, especially if the grade of ore is on the decline or there is a falling-off in the ratio between profits and the value of the mineral recovered. On the other hand, a tax on mining company profits has the obvious disadvantage from a government point of view of being subject to considerable variation between good times and bad.

After the payment of salaries and wages, the purchase of work stores and services and the meeting of tax obligations, what is left of mining revenue—net profit—is available for distribution as dividends to the shareholders of the company or for retention with a view to subsequent reinvestment in Canada. As indicated elsewhere, the majority of the companies operating in this country are owned and controlled by parent concerns or by individual shareholders in the United States, the United Kingdom and elsewhere. So far as this makes available knowledge, capital and assured markets, it is of considerable advantage to a country like Canada which traditionally has lacked many if not all of these things. Indeed, in the absence of enterprise from outside, and through it a supply of the necessary complementary factors of production, many of the nation's mineral resources may never have been exploited at all.

Nevertheless, dependence on foreign companies also involves certain disadvantages. These relate both to balance of payments matters and to the wider problem of development and resource utilization. For instance, when all or most of the company equity is held abroad, the fact that dividend payments are related to widely fluctuating profits and not necessarily to Canada's general foreign trade position may occasionally lead to remittances which bear little relation to the flow of foreign exchange which would be necessary to stabilize a difficult balance of payments situation. Secondly, although the rate and method of exploitation may be influenced by lease arrangements over the mineral property and by fiscal policy and various other government measures, it is the mining company which in the last analysis must determine the course which is to be taken under given market and supply conditions. Its criterion of success may thus be the profitability, not of a single mine, but of a much larger unit in which a smelter, refinery, several fabricating plants and various sales outlets may be involved. Under such circumstances the mining company's dividend policy and the government's fiscal policy may be poles apart.

Not all the company's profit is necessarily distributed. Indeed, a portion of it is customarily retained in the form of a capital fund. Some of this may be used for direct reinvestment, to prove up and develop new reserves of ore or to discover new mineral deposits. In this way, the expansion of many mines has been largely self-financed, and working life and capacity to earn foreign exchange continuously extended.

In summary, the more the mining industry pays out locally in the form of salaries and wages; the more equipment, processed materials and other commodities it buys from domestic sources; the more it contributes to government revenue rather than pays out in dividends; the more of its earnings it reinvests in the country, whether in its own or other enterprises; and the more it encourages local participation in ownership and control, the greater, in general, are likely to be the benefits which it will construe upon the nation in which its mining and other properties are located.

B. Trends in Production, Employment, Investment and Trade

There is no simple way in which the economic effects of a given industry or group of industries can be measured with accuracy. Statistics relating to their gross value of production are too comprehensive in that they include expenditures on goods and services produced in other sectors. Net value of production as reported by the D.B.S. excludes only outlays on raw materials, fuel and electricity. It therefore exceeds the true value added by each industry to the extent of depreciation and payments for such business services as advertising. Data on salaries and wages, on the other hand, tend to understate its contribution. They make no allowance for the fact that capital and certain other resources internal to the industry's operation are also vital to its operation.

Recognizing these shortcomings, attempts have been made in Canada and elsewhere to carry out a complete and internally consistent input-output analysis of the national economy, major sector by major sector and industry by industry. So far as was possible, the latter approach has also been adopted in the following analysis.

Comparisons in respect to international trade are useful. Yet dollar values are, again, gross values. Also commodity exports, regardless of their nature, are valued at their point of origin; not at the international boundary. Hence, in circumstances where an industry is integrated to the extent that it not only produces its products but also transports them to their destination outside of Canada, they therefore understate its contribution as an earner of foreign exchange. Import figures are different again. As published in *Trade of Canada,* they reflect the invoice price at point of entry. Provision for freight, insurance and handling charges and duties and other taxes consequently must be made if the delivered cost to the importer is to be properly evaluated.

Industries which purchase some part of their raw materials abroad, buy some of their machinery and equipment elsewhere, or are owned outside of Canada, further complicate matters. Tending to offset the sale of the industry's products outside of Canada are foreign expenditures on supplies and equipment and the payment of interest and dividends abroad. Allow-

ances of this kind must therefore be made if the industry's net earnings of foreign exchange are to be properly assessed.

Investment expenditures covering new construction and the purchase for the first time of plant and equipment are also significant. However, as reported by the D.B.S., they do not include amounts spent on such other transfer payments as the purchase of land, buildings and other existing physical assets. In some instances they therefore fall short of the industry's own balance sheet accounting of capital investment by as much as 10% or even 20%. Also there is the matter of import content. The direct effect upon the Canadian economy of an investment programme, the associated demands of which are essentially for the services of Canadian contractors and Canadian building materials and equipment, is obviously greater than another of comparable size whose capital goods are largely produced elsewhere.

In this chapter, each of these measures is reviewed in turn. Where possible each industry's output has been measured in terms of Gross Domestic Product—an approximation, which itself, is directly comparable with such economic aggregates as G.N.P. However, since detailed input-output analyses have only been carried out for the year 1949, such long-run series as net value of production, employment commodity exports and new capital investment have frequently been used in their stead.

(a) *Value of Production*

Forward looking estimates of production have already been discussed in volume terms. In order to convert these into dollar figures, price estimates have also been prepared. A rise relative to the general price level results, naturally enough, in even higher value figures; no change in real price, in a parallel movement in output values; and, where applicable, a decline in relative price, in a falling behind of the value of production series.

Table 36 summarizes the information available for 1955 and includes estimates for 1980. Among other things, it indicates that the selling value of all primary mineral products mined and processed by smelters and refineries in Canada may multiply three to fourfold over the next quarter century. The gross value of output of the nation's mining industry, in other words, may rise from approximately \$1.6 billion in 1955 to between \$5.0 and \$6.0 billion 25 years from now.

Since the over-all growth of the Canadian economy will be taking place at a lesser rate, the mining sector will be growing relatively in importance. At the present time the gross value of sales of the nation's mines, smelters and refineries etc., is equivalent to between 5% and 6% of Canadian G.N.P. If the accompanying estimates are borne out by experience their value of production in 1980 may have risen to an amount equivalent to between 7% and 8% of the nation's total output of goods and services.

Table 36

ESTIMATED VALUE OF PRODUCTION OF ALL PRIMARY MINERAL PRODUCTS, CANADA, 1955 AND 1980

(value in millions of constant 1955 dollars)

Mineral category	1955 ($ millions)	1980 ($ millions)
Metals	1,235	4,200
Industrial minerals[a]	187	750
Structural materials	228	550
Total	1,650	5,500

a Including artificial abrasives.

In the late 1920's the nation's mines, smelters and refineries were responsible for approximately 4% of the then Canadian G.N.P. Back around the turn of the century, mining, as an industry, was even less important relative to other types of economic activity in this country. Viewed in its historical perspective, the accompanying forecast is therefore for a continuation of a trend in national development which has been apparent for over a half century.

While gains are expected to take place in each of the major mineral product categories, metals will continue to dominate the Canadian scene. There over-all production may multiply about 3.5-fold. An even greater increase may be reported for the industrial minerals. Meanwhile Canadian production of the structural materials, because it will be limited essentially to domestic requirements, may go up about two and one half times during the quarter century under review.

Another and more interesting breakdown is that between mining and mineral processing. Expressed in value terms, their relative importance at the present time is in the order of 3 : 2. Were the accompanying forecasts as to aluminum metal production and the primary processing of uranium and titanium to be realized, the two may become more nearly equal in importance a quarter of a century from now. These expectations are quantified in Table 37. There mining, as measured in gross value of sales is shown as rising to about 2.7 times and mineral processing to nearly 4.5 times the value added by the nation's smelters, refineries and other primary manufacturing establishments in 1955.

Table 37

ESTIMATED VALUE OF PRODUCTION BY MAJOR INDUSTRY SECTOR, CANADA, 1955 AND 1980

Industry category	1955 ($ millions)	1980 ($ millions)
Mining	948	2,700
Mineral processing	702	2,800
Total	1,650	5,500

These statistics, though they give an impression of relative rates of growth must be reduced to the extent of purchases from other sectors of the economy if they are to be used in direct comparison with Gross Domestic Product. Such a conversion as is made in Table 38 also indicates that Canada's mining industries are likely to grow relatively in importance. Accounting for around 40% of the nation's resource industry output and for around 4% of total economic activity in this country in 1955, they may rise to around 50% and 5% respectively in 1980.

Table 38

ESTIMATED GROSS DOMESTIC PRODUCT AT FACTOR (COST), CANADA, 1955 AND 1980

(value in millions of constant 1949 dollars)

Category	1955 ($ millions)	1980 ($ millions)
Mineral industries[a]	734	2,700
Total Canadian G.D.P.	19,390	55,400
Mineral industries/total Canadian G.D.P.	4%	5%

a Excluding fuels, *i.e.* as conceived for purposes of this study.

(b) *Employment*

Another and more tangible measure of growth is direct employment. The nation's mining and mineral processing industries currently provide full-time jobs for some 110,000 Canadians. Based on the estimates of dollar value of output reported previously in this study, on stated assumptions as to the relative contributions of capital and labour, and on the estimates of labour productivity outlined in Table 39, employment in the exploration and development, mining and primary processing phases of the industries' activities may mount to approximately 200,000 persons in 1980. In its national setting, this performance is less striking than the outlook with regard to production and sales. Twenty-five years hence some 2.2% of the nation's total labour force will be working in these industries as compared with about 2.0% at the present time.

Table 39

ESTIMATED EMPLOYMENT IN THE MINING AND MINERAL PROCESSING INDUSTRIES, CANADA, 1955 AND 1980

Industry category	1955 (thousands)	1980 (thousands)	Assumed annual rate of increase in labour productivity
Mining	74	130	2.4
Mineral processing	36	75	3.0
Total	110	205	2.6 (approx.)

The number of employment opportunities arising in this sector of the Canadian economy have approximately doubled since the late 1920's. The average number of men employed in the nation's mines between 1926 and

1930 was 39,000. The average number engaged in primary mineral processing during the same period was approximately 16,000. Together they then accounted for approximately 1.6% of all Canadians with jobs. Since then, the proportion has varied, first in one way, then in another. The early years of the Depression saw a marked curtailment in mining employment. However, during the late 1930's as gold production became much more important, mining employment gained relative to the national total. Table 40, which is expressed in five-year averages, indicates both the long-term upward growth trend and swings which have occurred in job opportunities over the last 20 to 30 years.

Table 40

EMPLOYMENT IN MINING AND MINERAL PROCESSING RELATIVE TO ALL PERSONS WITH JOBS, CANADA, 1926-55 AND 1980

(per cent)

Period	1926-30	1931-35	1936-40	1941-45	1946-50	1951-55	1980 (est.)
Mining	1.1	0.9	1.5	1.1	1.3	1.4	1.4
Mineral processing	0.5	0.3	0.4	0.6	0.5	0.6	0.7
Total	1.6	1.2	1.9	1.7	1.8	2.0	2.1

Meanwhile the proportion of workers employed in the processing plants has gained relative to those employed in the nation's mines. One has almost doubled; the number of miners meanwhile has risen about 1.8 times. Over the next quarter century, employment in the nation's mines might rise from approximately 74,000 to around 130,000 and that in the various smelters, refineries and other primary manufacturing facilities from 36,000 to around 70,000 people.

In preparing these forward looking estimates, advantage, where possible, has been taken of historical data. The past long-run relationships between gross and net values of production and salaries and wages have been projected into the future. As for mining, salaries and wages have shown a modest decline relative to the total value of ores and concentrates mined in this country. This changing relationship was also assumed to apply throughout the 1960's and 1970's. In other words, the role of labour, as a factor of production, may continue to fall relative to capital and other factors of production during the quarter century under review.

When it came to processing, net rather than gross values of production were used as a point of departure. Here, again the ratio of salaries and wages to output is less in the 1950's than it was in the late 1920's. Labour costs, however, form a larger proportion of value added in the primary processing plants. The current ratio between salaries and wages and net

value of production in the nation's smelters and refineries is in the order of 30%. This has been assumed to be the case through to 1980.

In order to estimate direct employment it is also necessary to project man-year productivity and hours of work trends into the future. (A uniform reduction of 15% in the average hours worked a week was also expected over the 25-year interval from 1955 onwards.)

(c) *Capital Investment*

Another measure of the prospective growth of Canada's mining industry is capital investment. Currently the firms engaged in mining and the processing of minerals are investing $1 out of every $20 presently being spent on the creation of new physical assets in this country. In 1956 more than $400 million was spent either in the search for new mines or on the purchase of machinery and equipment and the construction of manufacturing plant and other facilities. Over the next quarter century this effort may increase to about four times the level attained in the early 1950's. Thus $1 billion may be spent annually on the capital facilities necessary to expand domestic consumption and exports in 1980.

If this is so, investment in the mining sector will increase relative to total investment in all industries in Canada. In recent years some 3% of all the capital being raised for this purpose was being paid out by individual firms and corporations concerned primarily with the extraction and primary processing of metals and industrial minerals. The relationship to the national total might be more likely 5%, 25 years from now.

New capital outlays could increase somewhat more rapidly at the processing level. This will happen only if Canada continues to manufacture 10% to 15% of the world's requirements of aluminum ingot and at the same time converts a larger proportion of Canadian-produced minerals into primary products than is the case at present. Otherwise, mining, as distinct from primary processing, is likely to account for the greater share of new capital invested in this important industrial sector over the next quarter century.

Table 41

ESTIMATED VALUE OF NEW INVESTMENT IN MINING AND MINERAL PROCESSING, CANADA, AVERAGE 1951-56 AND 1980

Industry category	Average 1951-56 ($ millions)	1980 ($ millions)
Mining	140	400
Mineral processing	110	600
Total	250	1,000

An important characteristic of the mining industry's investment programme is its import content. Many of the specialized engineering services and much of the machinery and equipment will continue to be purchased elsewhere. Heavy earth and rock moving equipment, numerous steel items and the services of market and other consultants will also continue to be purchased in the United States, the United Kingdom and continental Europe. On the other hand, most construction contracts and the majority of expenditures on repair and maintenance will be placed with, or result in a direct increase in activity in, other Canadian industries.

The import content of the average Canadian project is now around 25%. This will decline as a greater proportion of the necessary machinery and equipment becomes available from Canadian sources. In 1980 imports might be valued at around 20% of total capital investment. Due to the size of the over-all programme, in the vicinity of around $250 million in foreign exchange might then have to be found in order to cover the purchase of these capital goods in other countries.

(d) *Balance of Trade*

Over the past 20 to 30 years, metals and other minerals have had a marked effect upon the nation's balance of payments. Sales elsewhere have risen relative to total commodity exports. Meanwhile mineral imports have moved upward much more in line with the nation's over-all trade. This is indicated by Table 42 which relates the nation's mineral trade activity to total exports and imports over the years since 1926.

Table 42

INTERNATIONAL TRADE IN PRIMARY MINERAL PRODUCTS, CANADA, 1926-80

Period	Mineral exports $ million	% of total exports	Mineral imports $ million	% of total imports
1926-30	108	9	35	3
1931-35	77	13	16	3
1936-40	193	20	32	4
1941-45	315	12	60	4
1946-50	419	15	94	4
1951-55	859	21	155	4
1955	1,079	25	220	4
1980	4,000	35	750	5

Receipts of foreign exchange on mineral commodity account exceeded purchases abroad to the extent of $800 million in 1955. By 1980 sales of metals and other minerals, particularly in the United States, may push Canadian earnings of foreign exchange up toward the $4 billion mark. Imports, meanwhile, may more than treble. Canada would then have a favourable trade balance on mineral commodity account to the extent of

more than $3 billion. Under these circumstances, sales elsewhere would account for approximately one-third of Canada's visible exports. At the same time purchases outside of this country of commodities such as bauxite, alumina, iron ore and various of the alloying elements may rise to between 5% and 6% of the value of Canada's imports of all commodities.

In order to be comprehensive some allowance must be made for purchases elsewhere of engineering services, machinery and equipment. Additional demands for foreign exchange in the form of interest payments and dividends paid out to non-resident investors in Canada's mining industries must also be taken into account. Collectively the latter are likely to be such as to reduce the nation's favourable balance of payments from more than $3 billion surplus on commodity account to, say, $2.5 billion twenty-five years from now.

C. Mineral Development and Economic Growth

Traditionally, one of the more effective ways for fostering economic growth in relatively underdeveloped countries is the investment of foreign capital in mining and related enterprises. These expenditures have usually been made by non-resident corporations whose primary concern is one of securing assured sources of mineral supplies. Today in Canada this same incentive exists. Over the next quarter century capital will continue to flow into Canada for much the same reason. Not only are the United States and some of the more highly industrialized countries of Western Europe anxious to establish supplementary sources of supply in this country, but there is also a growing awareness of the fact that raw material production is the area in which private capital will continue to be most interested given an appropriate investment climate.

The subject of resource development primarily for purposes of servicing industries in other countries has received a good deal of attention of late. However, such discussion as has taken place has been only of a general nature. Few attempts have yet been made to make explicit the manner in which mineral development can lead to economic growth in a country like Canada where the resources are located. The remainder of this chapter is therefore devoted to a review of such statistical information as exists on the probable impact of mining and mineral processing on the rest of the Canadian economy.

It is necessary, at the outset, to deal separately with the extractive and manufacturing phases. Not only is mining inherently a different type of industry from primary processing, but the amount of its purchases and the revenue generated via other sectors of the Canadian economy also differs one from the other. Purchases of raw materials, chemical and other supplies are relatively more important in the case of smelting and refining. So,

usually, are expenditures on maintenance and such other services as are essentially local in character. The tax yield per dollar of sales may be higher or lower with respect to mining. This is a direct result of the various tax concessions made to the mining companies. On closer examination it would appear that, as a result of various incentives provided by the Canadian tax laws, ores and concentrates are priced in such a way as to minimize profits (and hence taxes paid) at the processing level.

Table 43 summarizes such statistical information as is available concerning the breakdown of total expenditures in mining and mineral processing in Canada. It shows that between two-thirds and three-quarters of the moneys reported as a gross value of production (or sales) by the mining industry are actually spent on salaries and wages, fuel and power, supplies, capital goods, maintenance and other services or paid out as taxes in this country. The proportion is higher in the case of the nation's smelters, refineries and other primary manufacturing plants. Ninety per cent or more of the value of metal and other processed mineral materials manufactured in Canada is passed on to other and related sectors of the economy in the form of salary and wage payments, energy purchases, outlays in respect to raw materials and other supplies, expenditures on buildings and machinery and equipment, maintenance and other services, or as tax payments.

Table 43

APPROXIMATE BREAKDOWN OF EXPENDITURES IN MINING AND MINERAL PROCESSING, CANADA, 1950-54

(% of net value of production[a])

Expenditure category	Mining	Mineral processing	All manufacturing
Salaries and wages	36	30	48
Capital outlays	16	17	11
Maintenance and repairs	7	11	6
Other services	4	22	15
Taxes	10	10	10
Net profits	27	10	10
Total	100	100	100

a Net value of production (or value added) = gross value less purchases of materials and supplies.

Salaries and wages, it appears, account for about 36% of the value added by mining. The corresponding figure for smelting and refining is closer to 30%. Outlays on services, which in both instances have a high Canadian content, are around 4% in the case of mining; over 20% in the case of further processing. Repair and maintenance outlays, again somewhat higher in the case of smelting and refining, involve primarily Canadian activities. Capital investment in respect both to mining and to primary processing absorbs between one-seventh and one-fifth of the revenues obtained from the sale or resale of mineral products. The Canadian content in this case is lower

due essentially to the need to import machinery and equipment and certain construction materials. It is when it comes to the declaration of profits on the one hand and the purchase of supplies on the other[1] that mining differs substantially from the manufacturing stages described elsewhere in this report.

The contrast is greatest in respect to the payment of income taxes. Profits before taxes as reported by the mining industry have varied from a low of 18% of gross value sales to a high of 63% over the past 30 years. They averaged 41% in the late 1920's and 33% from 1950 to 1954 inclusive. By comparison profits before taxes reported by the nation's smelters and refineries were equivalent to about 9% of their total value of sales in the late 1920's and around 7% in the early 1950's.

Table 44

GROSS PROFITS AND INCOME TAXES PAID BY THE MINING AND MINERAL PROCESSING INDUSTRIES IN CANADA, 1926-54

(expressed as percentage of gross value of production)

	1926-30	1931-35	1936-40	1941-45	1946-49	1950-54
Mining						
(i) Gross profits as % of G.V.P. . .	41	39	52	41	37	33
(ii) Income tax as % of G.V.P. . . .	—	—	—	—	7	9
Mineral processing						
(i) Gross profits as % of G.V.P. . .	9	3	4	5	7	6
(ii) Income tax as % of G.V.P. . . .	—	—	—	—	2	3
Total manufacturing						
(i) Gross profits as % of G.V.P. . .	6	3	8	8	9	8
(ii) Income tax as % of G.V.P. . . .	—	—	—	—	3	4

Table 44 illustrates, in summary fashion, the profit and income tax position of the Canadian mines and primary mineral processing plants in Canada since 1926.

The over-all tax yield for Canada has therefore been greater with respect to mining. How much greater, though, has depended also on the effective rate. As a result of special depletion and other allowances, in recent years it has worked out to around 25% of gross profits before taxes in the case of mining. Smelting and refining, being classified for tax purposes as manufacturing, do not benefit from these concessions. The federal income tax has therefore approximated 50% of the gross profits before taxes as reported by the nation's primary processing plants.

Conscious of the advantage to themselves of reporting as high a profit as possible on their mining operations and minimizing the profit position in respect to smelting and refining, the integrated producers have, for years, followed the practice of pricing their ores and concentrates at a maximum.

[1]Materials, fuel, power and other supplies work out at 15% of gross value of production for mining in 1950-54. The corresponding figures for mineral processing were approximately 59% and for all manufacturing, 56%.

The reported materials expenditures of the smelters and refiners have been correspondingly increased and the profit position in respect to primary manufacturing thereby held to a minimum. To the extent that this practice has been followed in Canada, the foregoing analysis of benefits to the Canadian economy is biased in favour of mining.

It remains to evaluate the over-all significance for Canada of primary processing in this country. Assuming (and this is an important proviso) that the operation is economic in a truly international sense, the benefit to the Canadian economy of converting ores and concentrates to such primary manufactured forms as metal in ingot form is an approximate doubling in income. This multiplying effect would be further enhanced by increased Canadian participation in the ownership stocks of mining companies operating in this country.

Note

As long as the Canadian mining industry has a strong tax incentive to maximize the price on ores and concentrates and thereby to minimize the profit position of the smelters and refineries, there does not appear to be much room for the operation of custom smelting and refining operations in this country. Any firm which attempted to set up its own facilities and to buy most of its ores and concentrates from others would find price considerations such as to discourage this practice. Only through corporate integration can full advantage be taken of the Canadian tax system.

9

GENERAL OBSERVATIONS

1. FROM WHAT has been said previously, it appears that the mining industry, together with its related processing activities, will become an even more important sector in the Canadian economy. In expanding to between three and four times its present size, it may maintain its lead over the mineral fuels, coal, oil and natural gas, and pass the forest industries during the quarter century under review.

This forecast differs in one important respect from those prepared elsewhere. Projections of mineral requirements on this continent and for Western Europe indicate that demand may rise more in line with such aggregate measures of economic growth as G.N.P.[1] The world market for metals, industrial minerals and structural materials could grow somewhat more slowly than Canadian output. What we have been saying in other words is that Canadian producers are expected to gain relative to their competitors in other countries during the 25-year period ending in 1980.

2. Though Canada possesses the physical resources necessary for the realization of this forecast, large amounts of capital are also required. These moneys will be forthcoming from two main sources:

(i) the reinvestment or ploughing back of earnings from existing Canadian operations; and

(ii) new capital, most of which will be provided by large United States and other foreign-based corporations concerned about their long-range mineral supply position.

Most mineral-using industries are becoming increasingly capital-intensive. At the same time, the demands which they are being called upon to meet are more persistent in character. Thus, they are finding it necessary to acquire mineral reserves sufficient to meet their requirements for as much as 20 or

[1]See *Resources for Freedom*, Vol. I, a report to the President by the President's Materials Policy Commission, Washington, June 1952; also U.S. Bureau of Census, Working Paper No. 1, *Raw Materials in the United States Economy, 1900-1952*, U.S. Department of Commerce, Washington, 1954; and *Capital and Output Trends in Mining Industries, 1870-1948*, (Occasional Paper 45), published by the U.S. National Bureau of Economic Research, New York, 1954.

30 years ahead. Under these circumstances they are inclined to favour the acquisition of resources which will remain under their own corporate control.

This has been one of the main incentives giving rise to the considerable increase in exploration and mine development which has taken place in Canada in recent years. That programmes of this kind will continue to characterize mineral development in this country, there can be little doubt. More Canadian mines will be integrated vertically with processing and fabricating activities elsewhere. Also, through long-term contracts, they will probably introduce a greater element of stability into Canadian mining than has been the case heretofore.

3. The changing character of the market will also have an effect on price. A greater proportion of Canada's export trade will be moving between subsidiary and parent. Either that, or it will be sold to government agencies under some measure of foreign control. Proportionately less of the nation's output of metals and other minerals will be traded on the open market. The working of supply and demand may, therefore, be subject to considerations of a corporate or national character which would not be as effective were Canadian production to pass through numerous hands on its way from the mine to the ultimate consumer.

Prior to 1950, Canada's mineral exports consisted chiefly of gold, copper, nickel, lead and zinc. These were, and still are, commodities which are sold to a wide range of customers. Over the next few years, iron ore, titanium and uranium will move rapidly to the fore. By 1965, their total value may exceed that of Canada's traditional mineral exports. Yet these latter products differ in that they are often sold exclusively to parent firms located elsewhere. The same applies to some of the newer industrial minerals like potash and fluorspar. Thus Canada's export trade may, as a result of these close corporate relationships, be influenced to an even greater extent by research, tax, defence production, stock piling and other foreign government policy considerations.

4. More often than not, it is the large foreign-based corporation which possesses the knowledge of the market and the financial resources necessary for the launching of new mining enterprises. Reliable estimates of demand are of first importance. An adequate supply of minerals can almost certainly be proven up if the need exists. Hence, the purchasing firm, over the long run, is usually in a stronger bargaining position than the would-be independent supplier of minerals.

Besides being in a position to write contracts extending over many years, the same mineral using corporations also can raise capital more efficiently. As they already have a considerable investment in processing and marketing facilities, they are usually more credit worthy than the independent mining

companies. Mergers of the two have frequently been consummated with these considerations in mind.

The principal market for Canadian minerals, as we have seen, will be in the United States and, to a much lesser extent, in Western Europe. Corporations whose principal operations are in those markets will, therefore, continue to dominate the Canadian mining industry. Meanwhile, it appears unlikely that a considerable equity in new mining enterprises will be offered to the Canadian public. (See Appendix B.) Under these circumstances, it is difficult to see how ownership and control in the mining industry can shift progressively into Canadian hands.

The trend, apparently, is in the opposite direction. The D.B.S., in its publication *Canada's International Investment Position, 1926-1954*, has indicated that foreign participation is on the increase. In 1948, 40% of the capital invested in Canadian mining, smelting and refining facilities was owned elsewhere. The corresponding figure for 1953 was 55%.[2]

If allowances are made for the relatively greater rates of growth of such foreign dominated industries as iron ore, it may turn out that by 1980, some two-thirds of the equity in Canadian-based mining and mineral processing operations will be owned and controlled outside the country.

5. The extent to which Canadian minerals have been processed prior to export is also a subject of concern. As local needs are often limited and the over-all Canadian market may take time to develop, the economics of building a smelter or refinery in this country may be unfavourable—at least at the outset. Graduated tariffs, levied by other countries and increasing with the degree of manufacture, frequently discourage processing in Canada. This is true particularly of minerals shipped to the United States, as that country's tariff structure is designed in such a way as to maximize the labour content of most products destined for ultimate consumption there. Ores and concentrates pay the least. Smelter and refinery products come next. Meanwhile, higher duties as usually have to be paid on fabricated and other semi- or fully manufactured goods are frequently such as to prohibit any trade whatsoever. The threat of increased tariffs or physical quotas have a similar deterring effect. Accelerated depreciation allowances, and subsidies in the form of government sponsored research programmes, will also continue to militate against the establishment of mineral processing facilities in this country.

Economic factors of a more fundamental nature will always play their part. Sometimes they favour on-site processing. On other occasions they dictate that the minerals be transported in ore or concentrate form to their

[2]This is probably an understatement. The Consolidated Mining and Smelting Company Ltd., for example, has been classified by D.B.S. as Canadian-owned and controlled. In fact, it is wholly owned by the Canadian Pacific Railway. As of December 31, 1955, only 14% of the common and preferred stock of the CPR was held by Canadian citizens. Forty-six percent was owned in the U.K., 31% was held in the U.S. and 9% was owned by other foreign nationals.

points of ultimate consumption. Iron ore, while its metal content can often be improved at the source, is generally shipped out to centres in which adequate supplies of coking coal and steel scrap are available. Gypsum, because its products deteriorate when handled, must be transported in its relatively raw state. Copper, on the other hand, is easily reduced and can be best shipped in its metallic form. Lead, zinc, and nickel may be smelted and refined close to the mines if low cost energy is available, and outlets for their by-products can be found. Uranium could fall in this latter class. Yet other circumstances, like plant construction costs, the availability of chemicals at competitive prices and assured markets must also be favourable before processing in Canada can be said to merit heavy investments in projects of this type.

Generally, energy must be available in adequate quantities and at low unit prices. At one time, water-power was the only Canadian resource meeting these qualifications. Large blocks have been harnessed to this end in Ontario and Quebec and, to a lesser extent, in British Columbia. More recently, it has become possible to build really large steam plants utilizing coal, oil or natural gas. Technological improvements have also helped to narrow the gap between the kilowatt-hour costs involved in generating electricity by thermal and hydraulic means. The outlook will be further complicated by the advent of nuclear power in large amounts and at competitive prices. Regional differences in the cost of electricity must, therefore, be assumed to be disappearing. Hence, Canada is gradually losing one of its principal advantages where the initial processing of minerals is concerned.

To some extent, natural gas and oil may be assumed to take the place of water-power. Chemical processing techniques are in the ascendency. Petroleum fuels and petrochemical materials make other methods of manufacturing possible. They may also result in a wider range of by-products. Western Canada should benefit from these developments. Yet oil and natural gas are more transportable forms of energy than is electricity. Exported to the United States, they may be supplied under conditions more favourable than those offered to prospective processors in Canada. In circumstances where the United States tariff also discriminates against the importation of manufactured products, it is difficult to see how sound plans for the primary processing of a number of Canadian minerals can be formulated in this country.

6. It may appear logical to assume that mineral materials of the type exported from Canada will usually be made available at comparable or lower prices to secondary industries in this country. This may or may not be the case. A recent Canadian government publication entitled *Report by the Tariff Board Relative to the Investigation Ordered by the Minister of Finance Respecting Basic Iron and Steel Products,* Reference No. 118, says in respect to iron ore:

> "The nature and extent of deposit-ownership by Canadian mills is, on balance, apparently less favourable than the position of the United States mills competing in this market. Somewhere around 40% to 45% of the pig iron produced in Canada is made from captive iron ore. Of this amount close to 55% comes from underground mining, and the greater part is of concentrating or beneficiating grade. In comparison, United States mills in general apparently have obtained a higher percentage from captive sources with most of it open-pit now requiring concentration to a larger and larger extent. United States Steel, for example, obtains almost all its ore from captive sources and the greater part is open-pit."
>
> "While Algoma and Dosco presumably have favourable transportation, it is considered that the position of the Canadian industry as a whole is one of higher overall cost than that of the mills with which it competes. This situation may improve somewhat in the future as United States mills face exhaustion of traditional sources and go to higher-cost production or transportation material. The extent of such change as may come about and its effect on competitive position is a matter for speculation."

While it is not possible to make a detailed comparison of such future costs as may be encountered by Canadian and United States producers, a recent statement by the Vice-President in charge of Raw Materials for Inland Steel in the United States (Annual Meeting, April 25, 1956) throws added light on this subject. In it, he said:

> " . . . through either full or partial production of raw materials, we have been able to deliver these materials to our plant at a lower cost than if we purchased them on the open market. If we had not produced or transported any of our raw materials in 1955, we estimate that our profits before taxes would have been lower by $10 million."

Inland at present obtains 85% of its ore from its subsidiary companies.

The inference which is to be drawn from these excerpts is clear enough. Unless Canadian secondary industries develop their own captive sources of supply (and hence tie the prices they pay for raw materials closely to costs), they may continue to be at a disadvantage relative to foreign firms, whose principal manufacturing activities are located elsewhere.

7. Considerable space has been devoted to the influence of technology. Process development and other research will have a great deal to do both with the character and location of these industries. In recent years, the United States Department of Mines and other foreign government agencies have invested considerable sums of money in new techniques and plant development. Generally speaking, this has been to Canada's advantage.

One of the results of these programmes, however, has been the establishment and subsequent expansion of mineral processing facilities in or close to the principal areas of consumption. Initial investments in plant and equipment have been made and operating personnel and techniques acquired which cannot readily be transported to this country. The nucleus of numerous processing industries has been established in this way. Hence, only when demand for a new product has reached considerable proportions and the construction of an entirely new and separate plant becomes advisable is there an opportunity for it to be located in this country.

As the amount of process research and development in Canada will be limited compared with that carried out elsewhere, we have assumed that the majority of new Canadian enterprises in the smelting, refining and other primary mineral manufacturing will tend to follow, rather than precede, similar developments elsewhere.

8. Mine development has often been looked on in the past as a convenient vehicle for the opening up of new territory. Special tax and other concessions have been granted with this end in view. Assistance in the form of docks and government railways has also been provided on occasion.

In future, policy makers may be more impressed by the fact that mining has become a larger, more profitable and increasingly stable sector of the Canadian economy. Like the forest industries, it will, therefore, be regarded more as a bread-and-butter industry. Under these circumstances, it may be called upon to devote more of its income to the support of other types of economic activity. Mining, in other words, may be treated more on a par with secondary manufacturing and the service industries-types of activity which do not receive the same preferential treatment with regard to duty rebates, the payment of income tax, transportation assistance, housing loans, etc. The commodity forecasts, outlined earlier in this study, have been made with the possibility of these altered circumstances in mind.

APPENDICES

Appendix A

HISTORICAL DEVELOPMENT OF THE CANADIAN MINING INDUSTRY

THE DEVELOPMENT of Canada's mining industry is today closely linked with the growth of the world's industrial economy, and the consequent demand for mineral products. There is a tendency, however, to attribute a longer history both to this international significance and to modern large-scale methods of extraction than either can rightfully claim. The capital-intensive, hard-rock mining which has come to symbolize the Canadian industry today scarcely goes back beyond the beginning of this century. Earlier developments were of a more anarchic nature, characterized by purely local demand, a large number of small workings, primitive extraction methods and only a superficial knowledge of geology. Moreover, the number of minerals for which there was an active demand was less than it is today. Leaving aside such indispensable non-metallics as salt, sulphur, clay and building stone, we find that, until a surprisingly recent date, most enterprise was directed toward the exploitation of the precious metals—gold and silver—and of a relative few of such others as copper, lead and iron. Of these, only iron was used in genuinely large quantities.

At the beginning of settlement, three and one-half centuries ago, the mineral resources of this new continent were, of course, a completely unknown quantity. Most of the early French colonists, having once realized that precious metals and gems were not to be picked up for the asking, paid little further attention to what might lie beneath their feet and turned instead to farming, fishing, trapping and lumbering. Governmental curiosity, on the other hand, remained keen enough to result in a number of explorations being carried out in Acadia and along the St. Lawrence. As early as 1604, Champlain commissioned picked men to search for minerals, and received enthusiastic reports of iron and silver deposits at St. Mary's Bay in Nova Scotia, and of copper on the Bay of Chaleur. In 1654, Louis XIV granted a concession to one Nicholas Denys to mine gold, silver and copper on Cape Breton Island. Denys announced the presence of coal on the island, but

little was done about it until the following century. As in all primitive communities, the immediate need was for tools and for more permanent construction materials. The building of fortifications and of governmental buildings, in particular, quickly led to the opening of stone quarries, and to the erection of lime kilns and brick-and-tile furnaces, especially in the neighbourhood of the three principal towns of Montreal, Three Rivers and Quebec. The rising local demand for such essentials as pots and kettles, ploughshares and cannon balls had brought the Sieur de la Portardière from France as early as 1667 to investigate the rich bog iron deposits of Baie St. Paul and of the St. Maurice valley. Seventy years later, in 1737, the first charcoal furnaces were opened near Three Rivers to exploit the latter. Despite state support, however, and the fact that it was for a long time the only foundry in New France, the Compagnie des Forges operated neither efficiently nor cheaply. Production was hampered by a scarcity of labour, while the cutting off of nearby forests brought rising costs for charcoal.

Nonetheless, the Three Rivers area, and the deposits in Bagot, Nicolet and Drummond counties continued to furnish ore until a comparatively few years ago. The furnaces at Radnor Forges, near Three Rivers, continued to operate until 1883, while that at Drummondville produced some iron up to the year 1911. The bog deposits were not inexhaustible, and as soon as the large iron ore resources in other parts of the continent were opened, such small deposits as these could play only an insignificant role in the industry. Nevertheless they were of great importance in the early history of Quebec, because of the ease with which they could be worked, the easy accessibility of the ore and the high quality of the iron obtained from them.

On Cape Breton, meanwhile, the early 18th century saw none too successful attempts being made to develop the island's coal resources in order to replace imports of foreign fuels into France. From the west, rumours of more precious minerals in the vicinity of the Great Lakes were widespread throughout the French period, but most actual exploitation continued to be carried out in the easily accessible sedimentaries of the St. Lawrence Lowlands and the Appalachian region. The primitive furnaces of Three Rivers, not the smelters of some mythical Eldorado, constituted the pioneer metallurgical effort in North America.

Following the British conquest, mineral development continued at an accelerated pace throughout the St. Lawrence valley. Almost on the heels of the peace treaty, an English attempt was made to develop the copper deposits of Michipicoten in the Lake Superior region, but they found, as the French had found before them, that such mines were still too remote to be economic. Heavy British and Loyalist immigration, on the other hand, brought with it a certain degree of industrial growth and the usual demand for tools and building materials. The St. Maurice forges, in their primitive fashion, continued to produce bar iron, cast-iron stoves, ploughshares and

potash kettles. As population spread westward, iron deposits were soon found in Upper Canada as well, particularly where the settlers had unwittingly strayed into the Precambrian formations north of Kingston. As early as 1800, a charcoal furnace was erected at Lyndhurst, to be followed by such others as that at Normandale in Norfolk county (1813) and at Marmora in Hastings county (1820). In 1822, the first gypsum mine was opened near Paris in the western peninsula, but for a long time the product—then used as a fertilizer—was restricted to local markets in the face of heavy Nova Scotian competition elsewhere. In the following year, Canada's first *bona fide* gold discovery was made on the Chaudiere River in the Eastern Townships of Quebec and was as quietly forgotten. Salt, lithographic stone and a dozen other minerals were uncovered during the slow westward advance of settlement, but only in rare cases was the time yet ripe for their exploitation.

In the Maritime colonies, on the other hand, several minerals had advanced to the stage of export. Nova Scotia's gypsum deposits had, in fact, been mined for export as early as 1770, thanks to their proximity to tidewater, and to the heavy demand for this mineral as a fertilizer in the exhausted agricultural areas of the eastern United States. Large gypsum beds were also quarried in New Brunswick, but, like those in Upper Canada, for local use only. Whetstones provided another export from Nova Scotia to the south. On Cape Breton, coal was at last being mined in significant quantities. During the period immediately following the conquest, its production had not been encouraged, as being contrary to the tenets of mercantilism. In 1826, however, George IV transferred the fields to the Duke of York, who gave them in turn to his creditors. These last formed the General Mining Association, and began to produce on a moderate scale. In view of the small home market, about half their output was sold in the United States. The Maritime iron mining industry was initiated about the same time, when a charcoal furnace was erected near Annapolis in 1825 to handle ores from the Nictau-Torbrook area. It remained in operation for only a brief period, however, as did that built at Stellartown three years later. It was not until 1849, when the Acadia Iron Works opened at Londonderry, that any sustained production was achieved in the colony. In the previous year, New Brunswick's first blast furnace had been erected near Woodstock.

In 1842, the first step was taken to place the hitherto haphazard process of mineral exploration in British North America on a more efficient and scientific basis. In that year, William Logan was appointed to organize a geological survey, "a plan of investigation as may promise to lead to the most speedy and economical development of the mineral resources of the country". He proceeded to study and correlate all the known deposits of Nova Scotia to the Great Lakes. Under his direction the coal deposits of Nova Scotia were to be firmly established, gold to be found in paying quantities for

the first time in Canada, copper prospects to be investigated and the first commercial deposit of the last metal to be brought into production. His early maps and reports, as accurate as they were voluminous, gave impetus to prospecting and played no small part in the ultimate development and growth of Canadian mining.

By mid-century, new developments were following upon each other thick and fast. In 1845, excitement over the recently-discovered mineral deposits on the south shore of Lake Superior spread to Canada and a minor boom resulted. Companies were formed in every large Canadian city, and armies of geologists sent out to explore the British or northern side of the lake. Optimistic but premature plans were even made to set up a smelter at Sault Ste. Marie. Several mineral deposits were indeed found, but again the cost of developing them proved too high, and the majority of the enterprises failed. The copper deposits of Bruce Mines on Lake Huron, however, proved an exception, and the mine became for a time one of the most important in the country. Around the same period, the Geological Survey reported the presence of copper in the Eastern Townships. Active prospecting was carried on during the early '60's and with rather more success than had been achieved in the Lake Superior region. The most famous of these mines was the Eustis, first opened in 1865 and operated continuously for almost 75 years.

In the western peninsula of Upper Canada, meanwhile, the sedimentary formations continued to yield up their treasures. Petroleum was discovered during the late '50's, and several wells yielded spectacular flows. The accidental discovery of salt by an oil drilling company near Goderich in 1866, on the other hand, brought an industry to Ontario which has increased in importance through the years. Within 20 years, salt wells had been drilled at various points along the shores of Lake Huron and the Detroit River. Consolidation by one or two large corporations eventually closed most of the smaller and unprofitable works, and improved the quality of the product. The resources still available are enormous, underlying as they do a large proportion of the peninsula, and are being used today not only in the manufacture of salt itself, but in that of caustic soda, chlorine and other chemicals.

Up until the middle of the 19th century, in both Canada and the United States, mining had not been too important a factor in national development, nor had prospectors as a class been numerous. In 1848, however, the United States acquired California from Mexico, and the discovery of gold there during the following year set off an economic explosion from one end of the continent to the other. An unprecedented rush of population to the Pacific coast took place. As the easier workings became exhausted and the labour-intensive placer operations gave way to hydraulic sluice and quartz mining, large numbers of redundant miners were set free to explore elsewhere. Migrating restlessly northward into British territory, they soon uncovered new

sources of gold, and set off a new series of rushes, to the Queen Charlotte Islands in 1852, to the Thompson and Fraser Rivers in 1858, and to the rich Barkerville-Cariboo fields in 1861. The effect of these discoveries on the development of British Columbia was incalculable. The actual amount of gold extracted was of some importance. but far more significant were the pursuits to which many of the miners turned after a few years in the placer camps—some seeing the possibility of prospecting for veins and other hard-rock deposits, and others adapting themselves to agricultural and business pursuits. By attracting this unexpectedly large population to the west coast, and by giving rise to the roads, shipping, banks, trading centres, farms and sawmills which serviced them, the gold rushes might be said to have been indirectly responsible for the admission of the colony to Confederation and for the building of the Canadian Pacific Railway.

Placer production reached its peak in the mid-sixties. From Cariboo, the search moved on toward the upper waters of the North Saskatchewan, the Peace, the Liard, the Stikine and the Yukon. The fur preserve of Rupert's Land, whose only previous claim to mineral development had been the crude manufacture of salt along the shores of Lake Winnipegosis, suddenly found itself invaded by prospectors on their way to the Saskatchewan and the Northwest Territories beyond. Even in the Maritimes, the Pacific gold rushes led to the prospecting of what were thought to be similar geological formations, a minor fever which resulted in a number of developments. Placer gold was found at Ovens, Nova Scotia, in 1861, while a large number of quartz mines were opened elsewhere in the same province, particularly in the Mooseland and Tangier districts. The veins, however, were small and narrow, and mining methods crude. The miners themselves were inexperienced, financing was inefficient and there was too little knowledge of the complex geological structure of the area. It was not until the '80's that improved methods and growing experience brought higher production. But the knowledge gained with so much difficulty in these Nova Scotia quartz fields was to prove of great value during the early days of hard-rock mining in other parts of the nation. Maritime gold miners, in fact, were to provide a backlog of experience similar to that provided by the tin miners of Cornwall, many of whom had migrated to the United States and were taking part in the mineral exploitation of that country.

In Lower Canada, gold fever took the form of a belated rush for the placer deposits of the Chaudiere in 1864, while in Upper Canada several quartz deposits were discovered. That found at Madoc in Hastings county in 1866 had the distinction of being the first gold discovery on Canada's Precambrian Shield. This was followed by several other discoveries in the eastern counties and, in 1878, by similar finds in the Lake of the Woods area. The latter, however, were more spectacular than productive. The rich deposits on the surface failed to persist in depth, and generally earned Ontario

such a bad reputation that it was some time before the later gold discoveries at Porcupine were taken seriously. Up until 1895, despite minor discoveries in almost every part of the country, British Columbia continued to produce the bulk of Canada's gold.

Following Confederation, mining developed at an increasing pace, thanks to growing industrialism, railroad construction, agricultural expansion and the spread of towns. One of the earliest finds of this period was also one of the most spectacular, that of the silver veins of Silver Islet in Lake Superior, discovered in 1868 by the Montreal Mining Company. Profitable operations were begun by an American syndicate in 1870, which were brought to an end only when the mine was flooded out during a storm 14 years later. In the non-metallic field, apatite (or phosphate of lime) was mined as early as 1870 at various points in Ontario and Quebec. It was exported chiefly through Kingston, and later from the Lievre River in Quebec—where it had been discovered as far back as 1829—to meet the European demand for fertilizer, following the exhaustion of the Chilean and Peruvian guano beds. The spread of phosphate mining in this area led in turn to the discovery of mica, with which it was often intermixed. The increase in urban population led to the usual development of stone quarries and brick and tile plants, especially near Toronto, with its extensive clay deposits and large population. In the Eastern Townships of Quebec, asbestos was discovered in 1877 during the building of the Quebec Central Railway, and began to be worked in the following year.

The '70's and '80's also saw a brief revival of iron mining in Ontario, thanks to postwar reconstruction in the United States and railroad expansion in the west. Most of these furnaces had been hard hit by foreign competition after 1848, when the completion of the St. Lawrence canals cut the cost of imported iron. The new markets, however, were large enough to embrace both the Canadian ore and the imported iron which had previously ousted it. Ships out of Kingston now carried ore to Cleveland from Leeds, Lanark and Frontenac counties. Such circumstances, however, were both exceptional and shortlived. In general, at least up until the beginning of World War II, it has been American raw materials which have fed the Canadian iron and steel industry, rather than the reverse. One of the rare exceptions has been the iron ore deposits of Wabana in Newfoundland, which were opened in 1895 to meet the growing demands of Canadian industrialism and railway construction. In 1896, the Ontario government recognized this lack of self-sufficiency by initiating bounties for the discovery and processing of iron ore, and three years later was consequently rewarded by the opening of the Helen Mine in the Michipicoten district. Newly erected blast furnaces at Hamilton and Sault Ste. Marie began by using this native ore, but once again the imported product proved better, and they shifted in time to American imports from south of Lake Superior.

Thus far, the location of Canada's mining development had been governed largely by considerations of transport. For one thing, the country's still limited industrial development prior to Confederation and for some years thereafter, had meant an equally limited home market for industrial minerals, with the result that metallic ores tended to be exported to more advanced nations. For another, Canada was not yet well enough equipped technically to carry out the processing of many of her ores, even for her own use. This was particularly true of the base metals, which not only fetched lower prices but presented more complex extraction problems than did many of the other minerals. Copper ore from Lake Huron, for example, had to be shipped overseas to Welsh smelters during the '50's and '60's, as did that from the Eastern Townships. The high cost of moving these ores out, not to mention that of moving heavy mining machinery in, confined development to locations within a comparatively short distance of the main water routes.

There was, in addition, a lack of real information as to the more inaccessible mineral-bearing formations inland, although the Geological Survey was doing its best to remedy that deficiency. Railroad construction across the Frontenac Axis had helped to some degree to open up the Shield in the extreme east. Built north of Lake Ontario to meet the demands of the lumber industry, these lines tapped the diverse mineral resources of the area, its gold, phosphate, mica and iron. The exploration and development of the Precambrian area further west, however, had to be limited for a long time to relatively high-grade deposits of the more valuable minerals along and near the shores of Lakes Huron and Superior. In the Cordillera region, the extreme inaccessibility of the inland areas largely restricted development to that of the placer gold deposits. In the whole 1,800 miles which stretched between British Columbia and Bruce Mines on Lake Huron, with some very minor exceptions, scarcely any mining was carried on until after the construction of the transcontinental railroad.

The sudden penetration of both the Shield and the Cordillera during the '80's by the Canadian Pacific brought a rapid expansion in metal mining. In British Columbia, placer operations had dwindled to a mere trickle by 1880. Active lode prospecting had begun in the southern part of the province shortly thereafter; a rising world demand appeared for copper and silver; and, with the completion of the railroad in 1885, prospectors fairly swarmed into the area. The American mining frontier had been spreading north and east from California into the inland empire of Idaho and Montana, and from the Pacific coast to Colorado the mountainous regions were being prospected. It was from this direction rather than from Vancouver that the mineral development of southern British Columbia was directed. The migration across the border had begun during the '60's as part of the northward movement of placer mining, and took the form of a short but intensive gold rush into the Kootenay area. In 1882, however, silver-bearing galena was discovered on

the eastern shore of Kootenay Lake and, four years later, silver and copper on Toad Mountain, a few miles from Nelson. The rush was on, and from Kootenay Lake prospectors spread out in all directions. The next discovery was in the Rossland district, where some of the richest claims in the province were laid bare. By the winter of 1893-94, the Le Roi mine was shipping out rich gold-copper ore, and in 1896 the first smelter began operations at Trail. Other outstanding properties were staked during the same period; the silver-lead-zinc deposits of Slocan in 1891, and the Sullivan lead-zinc deposits in the East Kootenay district in 1892, now probably the largest lead-zinc mine in the world, and the largest producing silver mine in Canada. The highly complex ore in the latter was hard to treat, however, and the first attempts at separating the lead and zinc were unsuccessful. It was not until 1923 that the flotation process enabled the Sullivan to come into its own. In 1891, the first copper claims were staked near Phoenix in the boundary district, ore bodies of such low grade that smelters were established locally. West of the boundary country, the Copper Mountain gold-silver-copper deposits were discovered near Princeton in 1892.

By 1900, mining was a thriving industry in the south, and a dozen or more smelters had been built to treat various ores, most of which have since been abandoned. During this first great period of expansion in the industry, British Columbia was pre-eminently the mining province of the nation. Whether or not this mining could be called a truly Canadian development is a somewhat more debatable matter. Both prospectors and capital originated largely in the United States, and for a time the industry seemed in danger of becoming economically tributary to Spokane, thanks to the ease of north-south communications. Although Canada soon countered this threat with the construction of a railroad across the southeastern part of the province, the latter has always seemed to have more in common economically with the states of Idaho and Montana than with Vancouver.

There was to be one more boom in the Cordilleran region before the turn of the century shifted the emphasis to Ontario. This was the dramatic discovery of placer gold in the Yukon. The news of the Bonanza Creek discovery in 1896 resulted in worldwide excitement comparable only to that of the California rush half a century before. During the winter of 1897-98, thousands poured up from the coast over the White and Chilkoot Passes into Dawson City. The most extensive development took place between 1898 and 1905, reaching a peak in 1900 when Canadian gold production reached a figure of 1,350,000 fine ounces. Within a few years after the first rush, however, the claims had been exhausted so far as primitive extraction methods went. Dredges appeared on the creek claims, to be followed by extensive hydraulic operations on the hill and bench claims. With the virtual exhaustion of the high-grade small man's placers by 1907, Canadian production fell away to 705,500 ounces, and most of the population drifted off to new

fields in Alaska, leaving the Yukon to those larger-scale, capitalistic types of development which had become necessary for profitable exploitation.

In the eastern Precambrian region, meanwhile, the new transcontinental railroad had been responsible for tapping the rich nickel-copper deposits of the Sudbury basin during the course of construction, thus providing Ontario with its first real toehold in the world of mining. For the first few years, there was some production from mines with a high proportion of copper in their ores, but serious large-scale exploitation had to wait for a solution to the problem of how to separate economically the copper from the nickel, and the development of uses for the nickel itself. Fortunately, two metallurgical discoveries were made during the same decade which promised such a solution. James Riley found in 1889 that relatively small amounts of nickel imparted a peculiar hardening and toughening effect to steel, while in 1892 two processes for the separation of nickel and copper were developed almost simultaneously by Dr. Ludwig Mond and R. M. Thompson. Given large enough markets, the way now lay open for a more complete utilization of the Sudbury deposits, and in 1900 the high-nickel Creighton mine went into operation. Two years later, the vast majority of workings in this area were merged into the International Nickel Company.

A landmark in American mining had been the discovery in 1859 of the fabulous Comstock silver lode at Virginia City, Nevada. In broad terms, it has been said that silver ended the poor man's day in mining, and ushered in the era of the financier and engineer. Crude hand devices and common sense, so effective in the past, were unable to cope with the depth and complexity of the vast silver workings, which required the adoption of methods hitherto unfamiliar on this continent. Technology was forced, almost for the first time in the United States, to adjust itself to new and unfamiliar geological conditions. The Cobalt camp was to fill a similar role in Canada. The construction of the Temiskaming and Ontario Railway, designed to tap the agricultural potentialities of the northern clay belt, had led to the discovery of the rich silver deposits in this area and to the rush of 1903. The camp proved to be the training ground of Canadian mining, not only as regards extraction methods, but in the stimulation of public interest in mining ventures. Hundreds of mines were incorporated, shares were made easily available, and public investment reached new heights. Although it was still confined largely to the precious metals, Precambrian mining could now be said to have begun in earnest.

In line with the Spanish maxim, "It takes a silver mine to find a gold mine", Cobalt's success supplied the capital necessary for the development of the neighbouring gold belt. Prospectors overflowed to the north and east, uncovering in rapid succession silver at Elk Lake and gold at Larder Lake (1906); silver at Gowganda and South Lorraine (1907); and gold in the Porcupine district (1908). During the next year, the initial Porcupine discovery was followed up by the staking of the rich Hollinger, McIntyre and

Dome claims. Between 1911 and 1913 a string of successful gold discoveries was made at Kirkland Lake, near Swastika.

These discoveries were fortunate in that they coincided with certain technical advances which made it possible to treat lower grade and more complex ores. In the previous century, most of the world's gold had been recovered either in the pure form as dust and nuggets, or by amalgamation with mercury, but in 1887 it was discovered that gold could be dissolved from its ores by a solution of potassium cyanide. In 1909 this operation was used in the processing of low-grade ore at Cobalt. Five years later, it was introduced into the camp at Kirkland Lake. With other technical advances being made in mining, ore handling, crushing and concentrating methods, lode gold mining was beginning to hit its stride.

On the west coast, new discoveries enabled the precious metals industry to hold its own at least. The Rossland camp, at one time the greatest lode producer in western Canada, had reached its peak in 1902 and was showing signs of dwindling reserves. By 1907 a similar trend was evident at Nelson's Silver King mine. As if to compensate for these, mining of the Nickel Plate gold ores near Hedley began in 1903, while the first copper concentrates were shipped from the Britannia mine on Howe Sound in 1905.

With the outbreak of World War I, attention was diverted to those metals which could be used in munitions. While wartime conditions checked the pace of active prospecting, high prices led to a considerable expansion of output from those base metal mines already in production—so much so that many became exhausted. The Rossland region underwent a heavy drain while the Phoenix and Deadwood mines, whose production accounted for nearly all the copper from the boundary district during their lifetime, closed in 1919. But the approaching exhaustion of the boundary reserves had already led the Granby Consolidated Mining and Smelting Company to acquire the Hidden Creek copper deposits on the Portland Canal soon after the beginning of the century, and in 1914 a smelter was opened nearby at Anyox. The St. Eugene mine at Moyie, once the largest producer of lead in Canada, was nursed through its declining years by a wartime bounty. The application of the electrolytic process for the refining of copper and zinc in 1916, and the rapid development of hydro-electric power, led to the adoption of that process by Cominco in the same year. By 1918, International Nickel's new refinery at Port Colborne had gone into production as, in the following year, did that of the British America Nickel Company at Deschenes, Quebec. Unfortunately, demand was still largely dependent on that for armour plate and munitions, and with the coming of peace this demand declined. In 1924, Deschenes was forced to close down.

After 1918, another burst of expansion got under way in the mining industry. In 1919, silver-lead ores were discovered at Keno Hill in the Mayo district of the Yukon, and two years later the first concentrates were shipped

to the smelters. For some years too, copper was produced at Whitehorse. The Premier gold mine, discovered in 1910 in the Portland Canal district of northern British Columbia, swung into full production with the War's end, and became the largest single producer in the province. In Ontario, high silver prices hastened the exhaustion of the Cobalt field, and though capital and labour migrated to new areas in South Lorraine and Gowganda, large numbers of mines were abandoned by the beginning of the Depression in 1929. Prospectors also moved into the Rouyn area of Quebec where, in 1921, the Horne mine was staked, later to become one of Canada's most important copper producers.

But probably the most important advance, in the base metal field at least, was the discovery of the froth flotation process for the recovery of metals from their ores. Particularly applicable to sulphide ores, it allowed the exploitation of deposits whose ores had hitherto been almost impossible to treat. Without it, few base metal mines would exist in Canada today. British Columbia probably reaped the greatest benefit. The exhaustion of most of her less complex ores during the War necessitated a determined attack on those which remained, particularly those of the Slocan and East Kootenay silver-lead-zinc mines. In 1923, nearly 30 years after its discovery, the Sullivan mine entered into continuous, large-scale production, thanks to the flotation process, as did the copper mines of Howe Sound. Three years later, Copper Mountain went into intermittent but important production. At the same time, the continuing development of hydro-electric power lowered the costs of extraction and processing.

The period between 1926 and 1929 was one of tremendous industrial development in the United States, and mineral demand, particularly for the base metals, rose. Exploration was hastened by such factors as the development of aviation, which laid open previously inaccessible areas; the construction of the Hudson Bay Railway through northern Manitoba; and the search of such large, established mining companies as Hollinger and Cominco for new properties. Such prospecting companies as Ventures Ltd. and Dominion Explorers were formed with public support, and resulted in exploration work being carried out over the whole of the northern portion of the Shield.

In 1929, the industrial stock market crashed in the United States, to be quickly followed by that in Canada. During the next few years, the price of base metals declined to an all-time low which prevailed almost until the outbreak of World War II. But the same depression which brought such gloom to base metals was the salvation of the gold mining industry. In January, 1934, the price of gold, which had been gradually increasing, was finally fixed by presidential proclamation at $35 (U.S.) per fine ounce. Under this stimulation, a search began for new properties from Nova Scotia to British Columbia. New mines sprang up on the Shield like mushrooms, and where before there had been only some 15 or so gold mines in profitable

operation, the number rose rapidly to 106 in 1942. All the 26 mines of western Quebec were developed during this period, as were the 9 mines of Thunder Bay district and the 12 of Patricia. In addition, some 25 properties were opened in the old established Porcupine-Kirkland Lake area and the country adjacent. A few of these properties, it proved, could have operated profitably at the old price of gold, but the majority could not. Still other areas were opened in eastern Manitoba and British Columbia.

With the outbreak of World War II, the positions of the gold and base metal industries were once more reversed. For a time, gold was needed to meet the purchase of war supplies from the United States and, though a number of the smaller mines closed, the year 1941 saw a peak production of 5,345,000 fine ounces. From then on, however, the need to conserve supplies, equipment and labour forced the gold mines to give priority to the requirements of the base metal industry. Gold production began gradually to decline and, with mounting costs for labour and supplies, and a fixed selling price for their product, more and more mines began to show declining profits and, in some cases, actual loss. In 1948, the federal government instituted an Emergency Gold Mining Assistance programme in an attempt to stave off disaster for the more marginal producers.

The War, on the other hand, completely revived the base metals industry, the demand for munitions overtaxing the productive capacity of most mines. An expansion took place in smelting and refining facilities for copper and nickel at Sudbury, Noranda and Montreal East, and for lead and zinc at Trail and Flin Flon. Contrary to expectations, postwar demand did not fall off appreciably, thanks to pent-up civilian demand as a result of wartime rationing of consumer and capital goods; United States stockpiling policy; the rehabilitation of war-devastated areas and the Korean emergency in 1950. Early in 1952 some slight recession took place, but the demand for metals rising out of the cold war again carried the industry forward to increased levels of prospecting activity and production.

Mining since the war, in fact, has been characterized by an impressive series of landmarks. The development of the petroleum and natural gas industry in the prairies has probably been the most important, followed closely by Canada's growing production and export of iron ore. Prior to World War II, this country had produced little or no iron ore, while from 1939 to 1944 the entire Canadian output came from the Helen mine at Michipicoten which had been revived by hostilities. The development of large deposits at Steep Rock, west of Port Arthur, and of even larger deposits in the Quebec-Labrador region, plus the political addition of Newfoundland, with its Wabana ores, has changed the picture radically. Other small deposits have been found and worked in British Columbia and at Marmora, Ontario. Today, with a production in 1956 of 22.5 million tons of iron ore, Canada ranks fourth in world production.

Another landmark has been the production of uranium, a mineral regarded as being of comparatively little importance in prewar days. The pitchblende deposits on Great Bear Lake, discovered in 1930, were at first developed for their radium content and a refinery was built at Port Hope. The development of nuclear fission, however, and the offer of premium prices for uranium, gave a tremendous impetus to prospecting and development over the past ten years. The Beaverlodge area in northern Saskatchewan became an important producer, while several mines have recently opened in the Blind River area of Ontario. By 1959, uranium may take first place in dollar value among the metals mined in Canada.

Other postwar events of importance have been the development of tungsten and asbestos deposits in British Columbia; zinc and lead in the Northwest Territories; copper-nickel deposits at Lynn Lake in Manitoba; asbestos and nepheline syenite in Ontario; copper in the Gaspé Peninsula; zinc and copper near Amos, Quebec; and base metals in New Brunswick. There is, in fact, an obvious trend away from the former situation of regional specialization, when iron ore came from Wabana; asbestos from the Eastern Townships; nickel from Sudbury, and zinc and lead from the Cordillera. High demands plus increasing availability of transport have not only opened entirely new areas, but have allowed the economic exploitation of long known but hitherto unworkable deposits. As exploration continues to move in from the fringes of the Precambrian Shield, it seems safe to predict an increasingly varied range of mining developments in Canada, as well as a vastly greater production

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Appendix B

CHANGING METHODS OF FINANCING IN THE MINERAL INDUSTRY

Introduction

The amount of money required today for all phases of mineral development from prospecting to production is considerably greater than that required a few years ago. This is only partially due to the general increase in costs that has taken place since World War II. The finding of mineral deposits, for example, used to be largely the role of the individual prospector, who looked for ore bodies which outcropped at the surface or for oil seeps which told of the presence of oil below the surface. Today's search is directed largely toward the discovery of completely hidden deposits which can be located only by detailed geological and geophysical exploration and whose existence must be proven by drilling. Again, as the hinterland is pushed back, communications become more and more expensive. All such factors contribute to the increased cost of the early stages of mineral exploration. Technological advances have, of course, taken place in all phases of the industry, making possible improved operating conditions, greater efficiency, a larger scale of operation, and lower unit costs. This very increase in the scale of operations, however, has brought with it the necessity for greater capital expenditures before a mine or an oil well can be brought into production. The need for a stronger treasury when launching a company today is obvious.

There are many methods of financing mineral exploration and development. Past practice has led to the general acceptance of a few standard procedures but very definite changes in trend have become noticeable within recent years. Although an important part of the funds required is still supplied by equity capital raised through the sale of mining shares to the public, there has been increasing resort to debt financing with public and institutional funds; to financial assistance by established mining companies and to government financial aid and participation. Nowadays, equity capital is

largely confined to financing the search for and the exploration of mineral deposits. Once the decision is made to proceed with development, resort is being made, more frequently than not, to less traditional methods of financing mining enterprises.

Equity Financing by the General Public

Because of the inherent risks of mining projects stemming from the fact that they involve wasting assets, their successful financing has required risk or venture capital. This has meant that the most satisfactory procedure generally has been to allot a percentage of the ownership equity to the providers of this capital. There are several standard methods by which this may be done: the company may sell its own shares, without using the services of a third party; it may deal with an underwriter, who purchases stock from the company and then resells it to the public (this is the usual method of financing mining projects in Canada); it may be financed through a syndicate; it may give calls on its capital stock, a method by which a company grants market operators the privilege of purchasing certain quantities of its shares within stated time limits at predetermined prices. This type of financing, however, is considered highly undesirable.

Equity financing through the sale of stock to the general public has traditionally supplied a large part of the initial capital requirements of the Canadian mineral industry. The purchaser of mining shares realizes that the money he supplies for exploration and development purposes may be lost to him forever or returned to him one-hundredfold. It is readily apparent, therefore, that the purchase of stock in a mining or oil company when it is first organized is a business venture which can only be classified as a gamble or a very speculative investment. At the commencement of operation by a mining or oil company, it is often impossible to appraise it and its chance of success, as can often be done in other industries. The money put up to take the first hazardous steps in mine making has been well called risk capital. While there is invariably risk involved in most industrial undertakings, it must, by the very nature of things, play a much greater role in the mineral industry. This characteristic may be illustrated by the fact that between the years 1907 and 1941, only nine (or 0.82%) out of 1,093 metal-mining companies incorporated or licensed in the province of Quebec were considered to be economically successful. In Ontario, during the 50-year period 1904-53, only 54 or 1.54% of all the metal-mining companies were economically successful, in the sense that they paid dividends.[6a]

Private Capital[3]

Capital available from individuals is usually limited by the range of personal contacts available to the vendor. Moreover, it is usually feasible

[a] Numbers refer to references in the bibliography at the end of this Appendix.

to seek capital from individuals only in early stages of a mining project when the amount of funds needed to accomplish the next step is small, within the range of $50,000 to $100,000.

Government Financing

In contrast to the United States, Canadian government aid and participation in mine financing has been relatively minor. Here the federal government has participated directly in the financing of uranium exploration, development, production and expansion through the Crown company, Eldorado Mining and Refining Limited. During World War II, another Crown company, Wartime Metals Corporation, participated directly in exploration, development and production of strategic minerals. Through this agency, for example, the federal government acquired and caused to be operated under contract a tungsten mine in British Columbia and a molybdenum mine in Quebec. It also financed a magnesium mine and plant at Haley, Ontario. During the war period too, the federal Department of Mines and Resources assisted the exploration and development of strategic minerals, expending funds on various drilling programmes, including oil shale deposits in New Brunswick. Similarly, it provided funds for the development of tar sands deposits in Alberta and loans for bringing into production fluorspar and chromium mines. During the Korean crisis the government financed a quartz crystal operation near Lyndhurst, Ontario. The instances, however, have been relatively rare when Canadian government funds have directly participated in financing Canadian mining projects. There are two principal reasons for this: the commitment on the part of the Canadian people to a system of free enterprise; and the fact that the mineral resources of the country, by the British North America Act of 1867, come under the direct jurisdiction of the province in which they are located. Consequently, governmental encouragement has more often been given indirectly. Examples of this type of assistance are: the three-year tax-exempt period for new mines, liberal depletion allowances, capital allowances for exploration and development expenses, cost-aid assistance to the gold mining industry, subventions to the coal industry, and purchase contracts for uranium and cobalt producers.

In the United States, government aid and participation in mine financing has expanded tremendously since the Depression of 1929-33 and continues to increase in scope, even though the various agencies handling government aid may have been initiated under legislation designed to meet temporary situations. Not only has the *Paley Report* recommended continued government aid to existing projects, but more and more established mining companies are taking advantage of government financial aid. The following ramifications[3] of the trend would seem to warrant study:

(i) a vendor is enabled to get financial aid from the United States Treasury under conditions which would not be allowed to public and private financial institutions under current federal and state security laws;

(ii) as long as the government continues to give financial aid and to take the ventures involving higher risks, less financial aid can be expected from private and public sources. In the long run, such public aid might disappear;

(iii) the government not only can take the larger risks, but also can pay for examination of the properties and the assembly and preparation of the necessary data for obtaining the financing;

(iv) government loans are being made to bring into production mining properties of a marginal nature which probably would not have been financed from public sources until a much later date. However, should any recession in the prices of metals occur, such marginal properties might require subsidy or be required to shut down.

The principal United States government agencies involved in mine financing have been Defense Minerals Exploration Administration (DMEA), Defense Materials Procurement Administration (DMPA), and Reconstruction Finance Corporation (RFC). These agencies have afforded help either by direct or indirect financial assistance, or by direct loans. Such aid has been obtainable for ventures in the explorative stage (DMEA), the intermediate development to production stage (DMPA), and the final major financing to production stage (RFC).

The Copper Range Company's White Pine project in the upper peninsula of Michigan may be cited as a recent example. This project called for the construction, in addition to a townsite, of all facilities for mining, milling and smelting for the production of 75 million pounds per annum of high-grade copper from a large low-grade deposit. In this, as in other similar cases government assistance had three principal component parts:

(i) a long-term loan of capital funds, through the agency of the RFC;

(ii) certification of a high proportion of the cost for accelerated depreciation;

(iii) a government procurement contract, providing for the purchase of a definite quantity of the plant's production, at a stated price.

It is readily apparent from this project alone that the United States government assistance programme provides capital for major mining projects on a basis with which no private or public financing agency or medium can

compete. In the absence of such government assistance, this project might have been delayed by an indeterminate number of years, and when undertaken would undoubtedly have been developed on a much smaller initial scale.

Even more significant, from the Canadian viewpoint, is the effect of the operations of these agencies on the mineral industry in this country. Thanks to the stimulus of World War II and the post-Korean defence programme in the United States, Canadian mining development has gained greater stability and a certain confidence. American requirements in the field of strategic raw materials have resulted in both direct across the border assistance to Canadian mines and a guaranteed market for their products. Recent examples are the RFC loan to Steep Rock Iron Mines Limited on the one hand, and the purchase contract between DMPA and Sherritt Gordon Mines Limited on the other. The effect of such assistance on the mineral industry in Canada has been much the same as that in the United States itself, the development of projects more rapidly and on a larger scale than would have been possible under any other type of financing.

Financing by Established Mining Concerns

Up to World War II, established mining companies played an important part in supplying financial aid for new mining ventures. In recent years, they have become still more involved in large-scale exploration programmes and in financing new discoveries through to production. While they exhibit considerable diversity in their methods of extending financial aid to projects brought to their attention, three basic patterns[3] emerge from a study of the entire field.

(a) *Option to Purchase*

This procedure is used when it is possible to set a price in relation to an appraised value and the amount of investment is not very large. Payments are usually made over a period of years in predetermined sums. Such sums generally bear a close relationship to the estimated amount of money that the property could afford to pay out as an annual royalty when brought into production, and these are applied against the price set in the original agreement. In many instances the mining company agrees to a more or less continuous programme of development to the production stage.

Under a working option, development work is carried out and paid for by the established company. After the execution of development work to the value of a stated sum of cash, the company may either allow the option to lapse or it may incorporate a new company and, exercising options provided for on the latter's capital stock, take down shares in consideration of work performed. The established company furnishing finances under a work-

ing option agreement invariably places its shares in the newly incorporated company in its investment portfolio.

(b) *Lease on a Royalty Basis*

This method applies in cases where it is not possible to fix a purchase price. It is not generally attractive to the mining company because the royalty may become burdensome on operating costs. A sliding scale royalty may be preferred in such cases. The company also prefers to have complete control over the property, especially if there is considerable investment required in surface and underground facilities.

(c) *Participation*

This plan has considerable variations depending upon the financial requirements and reliability of the vendor. The established mining company usually insists upon full management control and in most cases it prefers to make provisions for the eventual purchase of the equity retained by the vendor. Provisions are made for the company to recoup its capital investment prior to the division of profits. A practical modification of the participation plan is that of offering the vendor a reasonably good earning rate without having to participate in the cost of bringing the property into production.

An established mining concern can offer certain advantages to the vendor. It is likely to have the knowledge and staff to obtain early development results and solve difficult technical problems. It is usually in a position to market the product to greatest advantage and, most important of all, it usually has command of sufficient capital resources to finance the property through to production.

There is evidence that an increasing number of established mining companies are employing surplus funds by investing them in the stocks of other companies engaged in the mineral industry. Wilcox[1] recommends that established mining companies plan their investment portfolios so that their surplus funds are distributed over the following categories:

In cash, call loans and gilt-edged securities	25%
In Class (1) main mineral producers	20%
(2) less seasoned mineral producers	20%
(3) likely mineral producers	15%
(4) mineral prospects of merit	5%
(5) mining holding companies	15%
(6) prospects	Nil
Total	100%

There are innumerable examples today of the participation of established mining companies in the financing of new properties. Inland Steel Company's entrance into the Canadian mining scene by the payment of $8 million in advance royalties on an iron ore body under Falls Bay of Steep Rock Lake enabled Steep Rock Iron Mines Limited to finance development of its Errington underground mine in the middle arm of the lake. In this instance, Inland Steel will expend approximately $50 million through its wholly owned subsidiary, Caland Ore Company, to bring its leased ore body at Falls Bay into production. Noranda Mines Limited has expended approximately $50 million through its wholly owned subsidiary, Gaspé Copper Mines Limited, to bring its low-grade copper ore body at Murdochville in the Gaspé into production. As the mineral industry turns more and more to the exploitation of large low-grade deposits there will be increasing necessity for large-scale operations, large capital expenditures and an increasing reliance on the technical and financial resources of established mining companies.

Debt Financing With Company, Public and Institutional Funds

In an industry that has traditionally relied upon equity financing to raise its capital requirements, the entry of many well-known mining companies into the bond market in a major way focuses attention upon the use of debt as a new source of funds in mine financing.

Historically,[2] debt financing has played a very minor role in the raising of capital for the Canadian mining industry. The uncertainties involved in locating and bringing a mine into production have been too great a barrier, heretofore, to attract the interest of the normally conservative bond investor. Even when a mine has been brought to the production stage the bond investor is more than reluctant to lend his money to build and equip a mill or smelter unless he is reasonably assured that revenues from production will be sufficient to provide for the payment of his interest and the retirement of his principal over the life of the bonds. Ability to make such payments is a prime requisite of both the underwriter and his clients before making any commitments.

Even when debt financing was resorted to some years ago, there were relatively few cases of public offerings. More often the debt has been incurred in order to secure advances from a parent or affiliated organization, to finance the acquisition of one company by another through an exchange of securities, to settle creditors' claims or to effect a reorganization in capital structure.

Practically every form and type of debt instrument[2] has been used at one time or another, including first mortgage bonds, general mortgage bonds, income bonds, collateral trust bonds, sinking fund debentures, income debentures, demand debentures, debenture notes, production notes and income

notes. It was only possible to use these methods when the speculative or risk element had been reduced almost to the vanishing point. These debts were for short periods, in the majority of cases from three to ten years, and were undoubtedly determined by the estimated life of the mine at the time. The rate of interest was usually higher than was currently asked in other industrial loans or bond issues. Provision for repayment of the debt was often based on either a fixed or graduated amount per ton of production. In many cases the security was convertible into common stock, or was issued originally carrying a bonus of stock as a further inducement to the lender.

In view of the relatively few cases of public debt financing in the mining industry in the past, the question may be raised as to why a number of concerns have been able to resort successfully to this type of financing in recent years. The answer is that it has been made necessary by the greatly increased amount of capital required to finance a property through to production. It has been made possible by the increased evidence of security. For example, the $7 million bond financing of Barvue Mines Limited in 1951 and $19 million debenture issue of Gunnar Gold Mines Limited in 1954 were both conditional upon the existence of sales contracts. In Barvue's case, the contract was with the American Zinc Company of Illinois, a wholly owned subsidiary of American Zinc, Lead and Smelting Co. It was estimated that profits accruing under this contract would enable Barvue to retire its bonds prior to maturity. A similar situation existed in the case of Gunnar Gold Mines, which entered into a contract for the sale of a fixed amount of uranium oxide with Eldorado Mining and Refining Limited. In both cases, the contracts made by these companies were pledged as security for their respective debts. In Barvue's case, the parent company, Golden Manitou Mines Limited, also undertook to guarantee unconditionally the payment of principal and interest of Barvue's bonds as well as all other payments required to be made under the terms of the trust deed securing its bonds. Of the $240 million required by 14 uranium mining companies to finance current mine development programmes, 88.6% has been or is in the process of being raised by the sale of bonds and debentures. This situation is made possible by the existence of firm purchase contracts with the Crown company, Eldorado Mining and Refining Limited.

Institutional funds, such as those supplied by insurance companies, generally are available for mining projects only when there is large and long-term operation controlled by interests of demonstrated experience and competence. A current example of the use of institutional funds in a major mining project in Canada is the $145 million loan by a group of 15 American and 4 Canadian insurance companies to Iron Ore Company of Canada. This firm at a total cost of $258.6 million, has developed vast deposits of direct-shipping iron ore in the Labrador-New Quebec area, 365 miles north of Sept Iles in the Gulf of St. Lawrence. The balance of the financing required was

supplied by the six major American iron ore and iron and steel companies participating in the venture. These companies will receive regular shipments of iron ore according to the extent of their percentage financial participation. Another example is the Sherritt Gordon development of its Lynn Lake nickel-copper-cobalt property. This institutional financing of $24 million was conditioned by a firm sales contract with Defense Materials Procurement Agency in the United States.

Debt financing is especially suitable where the development is of a major character and large sums of money are required. It makes available a vast reservoir of capital which can be drawn upon when the usual sources of funds are inadequate to meet the requirements of present-day large-scale mining operations.

Source of Funds for Mine Development and Expansion Since 1945

In a survey of the methods by which 72 mining companies (exclusive of the fuels: petroleum, natural gas and coal) raised the funds required to finance new development and/or major expansion programmes since the end of World War II, it was found that the total amount of $1,330,500,000 was secured in the following manner. (See also figure at the end of this Appendix.)

Method			**Total**
Bonds and debentures	Bonds	36.0%	50.0%
	Debentures	14.0%	
Loans	Parent company or major interest	6.0%	9.0%
	Bank	3.0%	
Retained earnings			27.0%
Stock sales	Major mining companies	9.0%	13.0%
	Shareholders	1.0%	
	General public	1.0%	
	Unclassified	2.0%	
Miscellaneous sources			1.0%
Total			100.0%

The amount shown as raised by the sale of stock to the public may be somewhat low, but it is certain that the general order of magnitude is correct. Stock sales to the man in the street are undoubtedly still of fundamental importance in raising money for prospecting and exploration purposes, but they now play a relatively small part in financing the actual development of a min-

eral deposit. The entry of the small speculator into the market, in other words, has probably far less real effect on the fortunes of the mineral industry than might be supposed from the publicity given to such ventures.

Briefly, the development of a mineral deposit has lost much of the element of risk which formerly accompanied it. This is due not only to recurring large-scale demands for minerals and consequently frequent establishment of purchase contracts prior to development, but also to the thoroughness with which modern exploration programmes outline and prove an ore body. The impression still exists that there is some element of risk in the mining industry as is made evident by the bonus and stock purchase warrant provisions which accompany many bond and debenture issues. Nevertheless, in this second half of the 20th century, it is becoming increasingly evident that mine development is a sound business venture.

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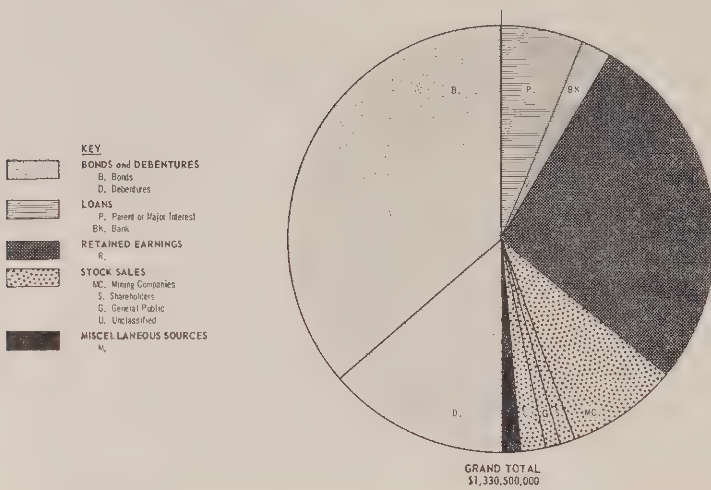
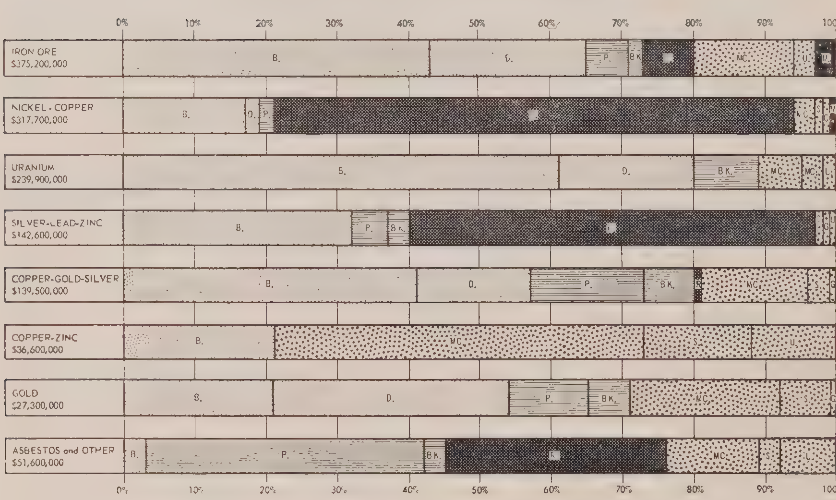
SOURCE OF FUNDS FOR MINE DEVELOPMENT AND EXPANSION
IN CANADA SINCE END OF WORLD WAR II
(72 COMPANIES)



SOURCE OF FUNDS ALLOCATED TO THE TYPE OF MINE DEVELOPMENT



SOURCE OF DATA
Company Annual Reports
Financial Post Cards

MINERAL RESOURCES DIVISION, MINES BRANCH,
DEPARTMENT OF MINES AND TECHNICAL SURVEYS,
JULY, 1956

Appendix C

FEDERAL TAXATION AND THE CANADIAN MINING INDUSTRY

THE CANADIAN minerals industry operates under the advantages of a stable government and favourable tax legislation. Where taxation has presented special problems to the industry, the tax authorities have demonstrated a willingness to adjust the law to fit new developments.

The Income Tax Act is the principal piece of tax legislation which affects the minerals industry, levying taxes on both personal and corporate incomes. With respect to personal incomes, the tax rate is on a graduated scale, and varies in direct relation to the amount of taxable income. The corporation tax rate, in respect of income earned on and after January 1, 1955, is 18% if the amount taxable does not exceed $20,000, and 45% on the excess over $20,000. An additional 2% is imposed under the provisions of the Old Age Security Act.

While the provisions of this Act affecting the mining industry are generally similar to those of the United States federal tax law, there are several important differences. Both percentage depletion and the privilege of deducting, as a current expense, outlays for exploration, discovery and development, which are the principal tax incentives provided for this industry under the United States law, are used in Canada; but the rules governing their application are different. The Canadian law also contains a special incentive device which has no counterpart in the United States—the three-year exemption from taxation for new mines. The rules governing depreciation, research expenditures and capital gains are also very different from those under United States law.

Briefly, the main provisions of the Income Tax Act which have special significance for the minerals industry in Canada are as follows:

(1) Rates of depreciation (capital cost allowances).

(2) Depletion allowances.

(3) Shareholders' allowances.

(4) Three-year exemption of new mines.

(5) Write-off of exploration and development expenses.

(6) Exemption of prospectors' and grubstakers' gains.

(7) Allowance for provincial mining taxes.

1. *Capital Cost Allowance*

A rate of capital cost allowance of 30% is allowed on mining buildings, machinery and equipment. This is well above the rates of 20% on equipment and 5% to 10% on buildings which are allowed to industry in general. On mine shafts, main haulageways and similar underground work designed for continuing use, the rate is 100%. These rates are applied under the diminishing balance method of depreciation, which permits a substantial recovery of the cost of the asset concerned during the early years. Use of the maximum rate of 30% has the effect of permitting a write-off of two-thirds of the investment in three years, although it may be spread over a longer period at the discretion of the taxpayer.

While this allowance may be subject to recapture in the event of the disposal of the depreciable property, which would modify the rapid rate of write-off, such recapture is rarely of consequence to the mining industry since disposal of assets is usually on a salvage basis.

The variety of bases on which similar assets may be depreciated under the income tax laws of the United States makes a general comparison with Canadian law virtually impossible. However, before recent legislation went into effect in the United States following the Korean emergency, it could safely be said that the Canadian deductions were substantially more generous than those allowed in the United States. This was due to a more general recognition and a more liberal application of the declining balance formula, which permits a flat and generally substantial percentage of the remaining unrecovered cost of the investment to be written off each year. Normal practice in the United States was to spread the depreciation of such assets over the life of the mineral property to which they were committed in proportions which reflected the rate of exhaustion of the property. Consequently, the rate of recovery tended to be slower than under the Canadian regulations. New legislation in the United States, however, has had the effect of narrowing this gap.

2. *Depletion Allowance*

A percentage depletion allowance is permitted as a deduction in the case of a mine operating in other than non-metallic bedded deposits (the latter

including such minerals as sand, gypsum, clay, gravel, building stone and peat). With the exception of gold mines, this allowance is 33 1/3% of the net profits reasonably attributable to the production of the mineral from any such property. An operator of a gold mine (a mine in which 70% or more of the output is gold) is given preferential treatment in that he is allowed to deduct either 40% of his net profits or $4.00 per ounce of gold produced, whichever is the larger.

Percentage depletion is primarily intended to be a deduction in lieu of amortization of the initial cost of the ore deposit, but is not limited to such cost. The depletion allowance to the operator of an industrial mineral mine occurring in a bedded deposit, on the other hand, is limited to the amortization of the cost of the mine over its productive life. This is quite unlike the deduction allowed in respect of other mines.

The term operator includes a person who has an interest in the proceeds of production from a mine under an agreement which provides that he shall share in the profits remaining after deducting the costs of operating the mine.

Under United States law, either cost depletion or percentage depletion may be used, depending on which gives the largest deduction. In the case of most metalliferous and industrial mineral mines, the rates applicable to specified categories of enumerated minerals range from 10% to 23% for percentage depletion, and are applied to the gross income from the mineral property. In cases comparable to the bedded deposits under Canadian law, the United States rate is 5% to 15%, depending on the mineral involved. Bedded and non-bedded deposits are not distinguished as such. The allowance in any one year, however, is limited to 50% of the taxable income from the property, computed without allowance for depletion.

While Canadian depletion rates seem superficially more generous than the American, the fact that the former are calculated on the basis of net income, and the latter on that of gross, makes it doubtful, over an extended period of time, whether Canadian deductions would be very much different from those allowed in the United States. The Bureau of Mines has estimated that, during the years 1944-48, dividends paid out by the metal mining industries (excluding gold) amounted to roughly 80% of net income after taxes (assuming a corporate tax rate of 33 1/3%) but before depletion. This means that the deduction allowed the dividend recipient under Canadian law (see following section) is the equivalent of an extra deduction of 12.8% at the corporate level. When added to the 33 1/3% allowed to the corporation itself, this produces a combined depletion deduction of about 46% of net income. Such a deduction will be larger than that available under the 15% of gross allowed by United States law, so long as the net income before taxes and depletion is more than 33 1/3% of gross income. Since, however, there is some doubt as to whether average net income actually does exceed this percentage by a significant amount, if at all, we must conclude that Canadian

and American depletion rates allow substantially similar deductions. It has been suggested, however, that the calculation of the deduction on the basis of net rather than gross income tends to accentuate the concentration of the benefits of percentage depletion among the investors in relatively profitable properties.

Where a person, other than an operator, has an interest in the proceeds from the sale of the products, or receives a rental or royalty computed by reference to the amount or value of the production from a mine, the deduction allowed is 25%. Under United States law, a portion of the percentage depletion allowable on the profits derived from a particular mining property is available to a taxpayer holding a royalty or other non-operating interest in that mineral property.

3. *Shareholders' Allowances*

Apart from the depletion allowances granted to operators and non-operators, shareholders resident in Canada may deduct an allowance in respect of dividends received from a corporation carrying on business in Canada, if 25% or more of that corporation's income is derived from mineral production. The rate of allowance varies from 10% to 20%, depending on the ratio of the income derived from mineral production to the total income of the corporation paying the dividend.

Shareholders receiving a dividend from a corporation that is not carrying on business in Canada are entitled to deduct an allowance of 15% of the dividend, provided that 50% or more of the corporation's income is derived from mineral production. Under United States law, no such allowances are granted to the shareholder on dividends paid out of earnings.

4. *Three-Year Exemption for Mines*

Under Canadian law, a three-year exemption is granted to corporations on profits derived from the operation of a new metalliferous or industrial mineral mine of the non-bedded variety. The period of exemption commences with the day on which the mine comes into production in "reasonable commercial quantities". During this period, the taxpayer is not required to charge depreciation on his investment. The practice appears to be to treat a mine as coming into production six months after the date when milling operations start at the mine, or when the company commences shipment of the ore, thus extending the exemption period to three and a half years. Such a powerful incentive to mineral exploration has no counterpart in the United States.

There have, of course, been certain administrative difficulties experienced in connection with this provision, particularly in the identification of a new mine, and in the determination of coming into production. In the former case, mining operations have been extended to new ore bodies on the same

property, new properties have been acquired adjacent to a previously existing property which had itself been granted an exemption, or there has been a drastic change in mining methods, such as the initiation of underground operations in what had previously been an open-pit mine. These problems, however, have been eased by a policy of giving the exemption an exceedingly liberal interpretation, so as to maximize its incentive effect, a policy which has been greatly facilitated by the general flexibility of the Canadian tax administration.

5. *Exploration and Development Expenses*

Canadian regulations permit the operators of coal, base metal, or precious metal mines, and industrial mineral mines with non-bedded deposits to write off their so-called preproduction costs after the mine comes into production. The operator determines the rate at which this write-off occurs, subject to the limitation that the deduction in any one year may not exceed 25% of the total preproduction cost of the mine. The cost of the property itself, or of option payments on the property, are not eligible for this treatment.

In addition, corporations whose chief business is that of mining or exploring for minerals may deduct exploration and development expenses incurred in the search for such minerals. These costs would ordinarily be considered to be of a capital nature, and would not be directly deductible in computing income without these special provisions.

Such a corporation may also deduct exploration and development expenses incurred pursuant to an agreement under which it undertook to incur the expenses in consideration for shares of the capital stock of a corporation that owned or controlled the mineral rights or in consideration for an option or right to purchase such shares. Under these circumstances, however, neither the owner of the mineral rights nor any other party to the agreement is permitted a deduction in respect of these expenses.

Exploration and development expenses incurred in any year are deductible in that year to the extent of the corporation's income from all sources. The effect is to authorize deductions in cases where the privilege of writing off preproduction expenses is of no value because the mining property is not brought into actual production. If the aggregate of such expenses exceeds the income, the excess may be deferred and deducted from the income of subsequent years, until such time as the full amount of such expenditures is recovered.

Under United States law, exploration expenditures incurred by corporations or individuals before the beginning of the development stage of a mine or deposit may be deducted up to a maximum of $100,000 in any one taxable year against income from any source. The deduction is available for

four taxable years, which need not be consecutive. The taxpayer may elect not to deduct these expenditures, and to the extent that they are available for deduction against United States income, they may be capitalized and recovered as a deferred expense. Any amounts in excess of $100,000, or incurred after the taxpayer has deducted such costs for four years, must be capitalized and added to costs recoverable through depletion.

United States law provides for the deduction of expenditures incurred after the presence of a commercial ore deposit has been proven. These are classed as development costs, and may be deducted currently or written off ratably over the life of the property.

No distinction is made under Canadian law between exploration and development expenses. The treatment of true exploration costs is more generous under Canadian than United States law, since the latter limits the privilege of treating as current expense the costs of exploring for and proving up a mineral deposit to $100,000 in each of four years. As far as development expenses are concerned, the benefits under Canadian and United States law appear to be approximately equal.

By a 1956 amendment to the Income Tax Act, a further benefit regarding exploration and development expenses was granted to the mining industry. Under its provisions it is possible for a company, when it acquires all or part of the mineral properties of another corporation through the issue or exchange of shares, to deduct from the income derived from the properties so acquired the exploration and development expenses incurred by the predecessor company in respect of those particular properties to the extent that these expenses would have been deductible if the properties had not been transferred.

6. *Exemption of Prospectors' and Grubstakers' Gains*

Bona fide prospectors and the persons who employ them or provide the financial backing for their prospecting activities are exempt from tax on amounts received from the sale of all or any part of an interest in a mining property acquired as a result of the prospector's efforts. If the consideration for the interest is shares of the capital stock of a corporation, rather than cash, any revenue derived from the subsequent sale of these shares is also exempt unless the owner disposes of them during or after carrying on a campaign to sell shares of the corporation to the public.

Amounts received from the sale of shares acquired by the exercise of an option which was accepted as consideration for the property are not exempt from tax.

This provision specifically exempts gains which might otherwise be considered to constitute the income from the prospector's regular work.

A capital gains tax is imposed at the time of sale of mining property in the United States. Losses are deductible on the abandonment of unsuccessful ventures.

7. *Provincial Mining Taxes*

Where a province levies a special tax on income derived from mining operations, a portion of the tax is allowable as a deduction in computing income.

8. *Excise Tax Act*

Under the Canadian Excise Tax Act a consumption or sales tax is applied with certain specified exceptions to all goods produced or manufactured in Canada or imported into Canada. The tax amounts to 10% of the producer's or manufacturer's sale price or, in the case of imported goods, to 10% of the duty-paid value. Certain goods purchased for use in mining are exempted from this tax. Likewise the tax does not apply to primary metals produced in Canada whether exported or consumed domestically.

9. *Customs Tariff*

All persons and corporations, including mining companies, are required to pay customs duties as imposed on goods imported into Canada under the items of a lengthy tariff schedule. The Act setting the duties of customs is known as the Customs Tariff and the rates of duties collected are in general according to: British Preferential Tariff applying to goods, the produce or manufacture of specified British countries, entering Canada without transhipment from a country enjoying the benefits of the British Preferential Tariff; Most Favoured Nation Tariff, applying to direct imports of goods the produce or manufacture of any British or Foreign country to which the benefits of the Most Favoured Nation Tariff are extended (the United States, which normally is Canada's largest source of imported goods, is in this class); and General Tariff, applying to all goods not entitled to admission under the Most Favoured Nation Tariff or British Preferential Tariff. There are also special rates under trade agreements with certain countries.

Many articles of mining machinery and equipment enter Canada free from customs duty under each of the tariffs, the free entry in some cases being only for articles of a class or kind not made in Canada. In other cases free entry is restricted to the British Preferential Tariff. A large number of articles having to do with metallic mining and metallurgical operations, and other mining operations are included in the various tariff items which single out many articles of mining machinery and equipment for either free entry or the imposition of moderate tariff rates.

Appendix D

PROSPECTS FOR THE PROCESSING OF IRON ORE IN CANADA

THE EXTENT to which the primary iron and steel industry will require ore for the Canadian metal market is discussed in the study, *The Canadian Primary Iron and Steel Industry,* published by this Commission. From this it is apparent that the amount of new metal required by secondary industry in this country will be small relative to total Canadian iron ore production. Some consideration should be given to smelting prior to export of ore destined for metal markets elsewhere.

That a substantial export trade in primary metal is likely to develop is denied by past experience. Rarely have blast furnaces, open hearths and steel rolling mill facilities been built to serve markets which were essentially international in character. Capital costs associated with the erection of facilities of this kind in or close to the principal mining areas are usually high. Interest and other carrying charges, because they reflect the uncertainties inherent in trading across international boundaries, are often above those encountered in the more highly industrialized steel consuming centres. Other materials, particularly coking coal and steel scrap, would have to be brought in, often over considerable distances. They would, therefore, cost more per ton than were they to be laid down in the northeastern United States, the United Kingdom, West Germany or Japan. Supporting services, including those necessary to maintain a large integrated mill in continuous operation would have to be established purely for this purpose. Thus, with the exception of the ore itself, expenditures would average out higher (and in the case of maintenance and like services much higher) than would be the case were the mills to be located in, or close to, the principal markets which they were designed to serve.

Depending upon the capacity of the plant and the type of process used, iron ore ranges from about 25% to as much as 40% of the total cost of pig iron production. Large blast furnaces of approximately 1,200 tons

per day of pig iron capacity, under average United States experience, indicate an iron ore to total cost ratio of approximately 30%. Electric smelting furnace studies on a 100 tons per day scale indicate a ratio more in the order of 25%. Proportionately, these outlays would be reduced by siting the plant close to the mines and hence reducing iron ore transportation costs.

Further economies are achieved by closely integrating primary furnace and steel rolling mill facilities. Serious heat losses are encountered if steel ingots from the furnaces and open hearths are allowed to cool prior to fabrication into sheet, plate, wire and other semi-finished products. Top gases, removed from the blast furnaces can only be used efficiently and coke oven by-products be sold profitably if there are steel fabricating, chemical and other industries located nearby. Considerable economies are also affected by closely scheduling the output of the furnaces to the capacities of ancillary plant further along the production line. Close liaison in preparing each melt is even more essential. These influences have led to the virtual disappearance of non-integrated producers of pig iron and primary steel. Yet there are others, like tariffs and import quotas which have also continued to militate against the smelting of iron ore outside the latter's main areas of consumption.

While the steel industry continues to employ processes and a process sequence first introduced in the 1860's and 1870's, other methods are attracting attention. One makes more extensive use of the electric furnace; another, the Wiberg process, can be used to produce sponge iron directly from iron ore using natural gas. A third, more radical in concept, employs hydrogen instead of coke to remove oxygen from iron ore. Each, being operable in smaller units, promises to make primary steel capacity more readily financed in circumstances where the long-term market for metal remains uncertain.

Using what is known as the Tysland-Hole furnace, electric smelting has become fairly well established in the Scandinavian countries. Norway, having pioneered the use of smaller units, is now reported to have furnaces in operation capable of producing 150 tons of pig iron per day. Similar facilities are known to exist in Sweden, Finland, Italy, Switzerland, Yugoslavia, Japan, India and Peru. Using hydro-electric power (hence minimizing coal requirements) these facilities are known to be competitive in blast furnaces of a more conventional character.[1]

Unless electricity can be obtained at rates of less than five mills per kilowatt-hour, the electric smelting of iron ore leaves something to be desired. The furnaces themselves cost less to build per unit of output. Coking coal requirements are only about half those of a blast furnace of equal capacity.

[1]At the present time, there are over 40 electric furnaces manufacturing pig iron in operation. The largest employs 20,000 kilowatts of annual generating capacity. In total, they are turning out better than one million tons of pig iron a year. A list of the locations and capacity of these plants is contained in a study entitled *A Study of the Iron and Steel Industry in Latin America*, Vol. II, proceedings of the expert working group held at Bogota, United Nations Department of Economic Affairs, 1954.

The grade of the ore and the quality of the coke can also be lower. Fewer by-products, either as heat or as organic chemicals, are generated in the process. Yet these advantages, unless electricity can be obtained quite cheaply, are usually offset by higher wage, electrode and other operating costs. (See Table I for a comparison of the estimated cost of producing pig iron by different processes and in plants of various sizes.)

Another possibility, previously mentioned, is the Wiberg process. Producing sponge iron, it can be used to greatest advantage in circumstances where few impurities are present in the ore and where a clean fuel like natural gas can be obtained at a comparatively low price. In eastern Canada where high-grade ore is available, natural gas will continue to be expensive. In western Canada, on the other hand, there is no lack of energy. Ore of a quality which can be treated by this process must, however, be imported. Should iron ore resources which meet these specifications be uncovered, the Wiberg process would warrant careful consideration, not only for meeting local iron requirements, but also with a view to exporting primary metal across the Pacific to Japan.

Carbon in the form of coke has long been used as a reducing agent in the conventional blast furnace. The introduction of oxygen instead of air in the blast has helped to reduce this requirement. So has beneficiation of the ore itself. Now considerable effort is being devoted to the substitution of hydrogen for coke. Recent experience in this connection suggests that the steel-making process may be further altered and improved during the quarter century under review. Natural gas, if cheap enough, could be used as a source of low-cost hydrogen. Yet a high-grade iron ore is also required. This qualification together with certain product market limitations may continue to prevent this technology from influencing the steel mill development pattern in western Canada.

When it comes to the conversion of pig iron to steel the availability of scrap assumes greater importance. Half of all the material charged to the average North American steel furnace is of this character. One out of every four tons entering the steel-making process consists of steel scrap returned by other manufacturing industries located nearby or in the form of obsolescent scrap accumulated by dealers from worn out vehicles and other equipment, demolished structures and the like. A conventional steel mill located at a distance from the nation's main centres of population and industry would obviously be at a disadvantage in this respect.

A continuing high level of operation is essential if the capital charges characteristic of steel production are to be spread over a sufficient volume of output. Fully integrated mills cost anywhere between \$250 and \$350 per ton of annual capacity. As a prior condition of financing, investors would

have to be assured of a volume of sales commensurate with the plants' capabilities over a period of, say, 20 years.

Where are these export markets likely to be found? Most of the underdeveloped countries of South America, Africa and the Far East, anxious to become self-sufficient with respect to primary iron and steel, can be expected to curtail their purchases once they have facilities of their own. Import tariffs levied on semi-fabricated steel products entering the United States are moderate to high. Western Europe tends to be an exporter rather than an importer of primary iron. Capacity elsewhere is increasing rapidly and the newer plants are extremely efficient. Across the Pacific, Australia and India are becoming firmly entrenched. Possessing high-grade iron ore and excellent coking coal resources, they are likely to take over most of the international trade which develops in the Orient.

It would therefore seem likely that Canadian exports of primary iron and steel will continue, as in the past, to be incidental to the manufacture of steel shapes for domestic consumption. Periodically, as large new additions to capacity are brought into production, surplus metal will be available for sale in the United States and abroad. From time to time, exchange arrangements whereby pig iron or steel billets were sold into the United States in return for certain semi-fabricated products may also be effected. Steel rails, pilings, pipe and other heavy products may also be sold intermittently and as currency considerations permit. However, relative to the contained metal content of the ore exported to steel mills on this continent and abroad, the tonnage of iron leaving this country in metal form is likely to remain small.

Table A

ESTIMATED COST OF PIG IRON OR SPONGE IRON PRODUCED BY DIFFERENT PROCESSES

(dollars per ton, except as indicated)

Item	Blast furnace: American practice (1 furnace) 800 tons per day of pig iron[a]	Blast furnace: American practice (1 furnace) 400 tons per day of pig iron[a]	Blast furnace: Swedish practice (2 furnaces) 200 tons per day each, of pig iron[b]	Tysland-Hole furnace (3 furnaces) 100 tons per day each, of pig iron	Wiberg furnace (2 furnaces) 64 tons per day each, of sponge iron
Iron ore	16.37	16.37	18.11[c]	16.37	16.37
Coke[d]	11.70	11.70[a]	8.58[b]	5.85	2.86
Limestone[d]	1.50	1.50	0.56[e]	1.50	0.22
Total, assembly costs for raw materials	29.57	29.57	27.91	23.72	19.45
Less net coking credit	—1.27	—1.27	—0.93	—0.64	—0.31
Less credit for blast furnace gas	—1.90	—1.90	—0.99[f]	—1.75[f]	—
Electrodes	—	—	—	2.01	0.40
Power[h]	—	—	—	22.50	8.10
Magnetic separation	—	—	—	—	1.50[i]
Cooling water	0.42	0.84	0.42	0.33	0.06
Repairs and overhead	2.10	4.20	2.10	0.95	1.65
Total, other transformation costs	—0.65	1.87	0.60	23.40	11.40
Direct wages	1.22	2.44	2.44	3.80	3.00[j]
Indirect wages and salaries	1.57	3.14	1.57	3.80	3.25
Total, wages and salaries	2.79	5.58	4.01	7.60	6.25
Direct costs	31.71	37.02	35.52	54.72	37.10
Capital charges	9.12[k]	10.86[k]	12.63[k]	5.82[l]	4.00[m]
Total:					
Including power at $0.009 per kilowatt-hour / Including power at $0.003 per kilowatt-hour	40.83	47.88	45.15	60.54	41.10
Cost of installation (millions of dollars)	28.50[k]	19.00[k]	22.10[k]	8.00	2.25
Assembly and energy costs as percentage of direct cost	93.2	79.9	65.6	88.1	75.3
Furnace burden (tons per ton of pig iron):					
Iron ore	1.54	1.54	1.7	2.00	1.54
Coke[n]	0.90	0.90	0.66	0.45	0.22
Limestone	0.40	0.40	0.15	0.40	0.06

See following page for footnotes.

Table A (Cont'd.)

FOOTNOTES TO TABLE A

a Average blast furnace practice in the United States.

b Average blast furnace practice in Sweden.

c Concentrates; to obtain low coke rate, it will probably be necessary to sinter before charging, an operation estimated to cost about $2.40 per ton of iron content.

d Net cost of coke $9.10 for 0.7 ton — $13.00 per ton of coke and $6.50 per ton of coke fines; coking credit is $0.99 per ton of coal or $1.41 per ton of coke; limestone, $3.74 per ton.

e Limestone, 0.15 ton per ton of pig iron.

f Value of total B.t.u. in blast furnace gas per ton of pig iron.

g Electrodes, 0.015 ton at $134 per ton for Tysland-Hole furnace and 0.003 for the Wiberg furnace.

h Electric power at $0.009 per kilowatt-hour.

i This sponge iron product may require magnetic concentration and will require heat for melting before refining; cost of magnetic separation and handling is estimated to be about $1.50 per ton of iron.

j M. Wiberg, "Relation of Type of Ore to Smelting Processes", in source cited below.

k Cost of a blast furnace plant complete, erected in 1953 in the United States, $30 million. In 1948 prices, the cost would have been $28.5 million, about equally divided between blast furnace and coke ovens. Calculations for the 400-ton furnace were made using the "six-tenth" factor. The 200-ton furnace installation cost was similarly estimated, except that two furnaces (200 tons per day each) were required. If more accurate costs for the installation of a 200-ton furnace were available, the total might be altered. Amortization is calculated at 8%.

l Capital cost: $8 million, or $72.73 per ton of annual capacity, at 8% for amortization.

m Capital cost: $2.24 million, or $50 per ton of annual capacity, at 8% for amortization.

n Coke consumption per ton of pig iron, not coking coal (one ton of coking coal is equivalent to 0.7 ton of coke).

SOURCE: *Survey of World Iron Ore Resources Occurrence, Appraisal and Use*, United Nations, Department of Economic and Social Affairs, New York, 1955.

Table B

ESTIMATED COST OF PRODUCING STEEL INGOTS IN A 250,000-TON PLANT USING DIFFERENT REFINING PROCESSES[a]

(dollars per ton, except as indicated)

Item	80% open heart[k] 20% Bessemer[b]	100% open hearth[c] 50% hot metal charge	100% electric furnace[d]			80% Bessemer,[e] 20 % electric furnace[f] cold charge
			Cold charge	50% hot metal	100% Bessemer[e]	
Liquid pig iron[a]	31.36	22.58	3.55	22.50	42,58	34.72
Circulating scrap[g]	6.28	—	—	—	3.68	2.94
Purchased scrap[g]	4.78	20.32	36.49	20.25	—	7.30
Ferroalloys	1.92	2.03[h]	1.50[h]	1.87[h]	1.23[h]	1.28[h]
Total, ferrous material cost	44.34	44.93	41.54	44.62	47.49[e]	46.24
Direct wages	4.74	4.75	3.56	3.34	2.00	2.31
Indirect wages	1.05	1.29	1.34	1.24	0.90	1.25
Total, wages	5.79	6.04	4.90	4.58	2.90	3.56
Fuel oil	1.06	2.04	—	—	—	—
Limestone and refractories	1.10	1.68	1.46	1.39	0.90	1.00
Compressed air and steam	—	—	—	—	0.50[j]	0.40[i]
Purchases electric energy	[j]	[k]	4.73[i]	4.23[j]	[k]	0.85[i]
Electrodes	—	—	2.22	1.85	—	0.44
Maintenance materials	0.50	0.21	0.21	0.21	0.15	0.21
Moulds and stools	—	0.67	0.87	0.87	0.70	0.75
Overhead, materials and services, utilities	0.57	1.39	1.38	1.38	1.00	1.30
Total, fixed production expenses	3.23	5.99	10.87	9.93	3.25	4.95
"Cost above metal" charge	9.02	12.03	15.77	14.51	6.15	8.51
Total, direct costs	53.36	56.96	57.31	59.13	53.64	54.75
Capital charges (8% for fixed charges)	4.64	4.03	2.39	2.39	2.22	2.30[m]
Total cost	58.00	60.99	59.70	61.52	55.86	57.05
Cost of installation (millions of dollars)	14.5	12.605	7.46	7.46	6.945	7.20
Ferrous material and energy costs as a percentage of total direct cost[n]	85.0	82.5	84.6	85.7	89.5	87 6
Ingot yield (per cent)	90.3	87.0	91.3	88.0	87.0	88.6

See following page for footnotes.

Table B (Cont'd.)

FOOTNOTES TO TABLE B

a Pig iron costs and scrap costs, calculated for an 800-ton per day furnace, are $40.83 and $36.75, respectively.
b Pig iron cost is here based on $40.83 per ton.
c For source and furnace charge see tables 20 and 29 of source cited below.
d For source see table 20; for charge, see table 26 of source cited below.
e Calculated on the basis of 10% scrap, requiring, per ton of ingots, 1,043 tons of pig iron, 0.10 ton of scrap and 0.006 ton of ferroalloys, with 87% yield; data from S. L. Case.
f For charge see table 26 of source cited below.
g Scrap value calculated at 90% of pig iron price; that is, $36.75.
h Including furnace addition of ore and deoxidizers (ore at an Atlantic coast plant $10.63 per ton).
i Compressed air required to blow metal is 600 cubic metres per ton.
j Assumed to be produced in the plant, included in "general and miscellaneous costs" (see next to the last item in table 24).
k Included in utilities.
l Power at $0.009 per kilowatt-hour.
m Allowance made for a 20-ton to 25-ton electric furnace connected to a 7,500-kilovolt-ampere transformer.
n Including power and electrodes or air.

SOURCE: *Survey of World Iron Ore Resources Occurrence, Appraisal and Use*, United Nations Department of Economic and Social Affairs, New York, 1955.

Appendix E

STATISTICAL TABLES

XIV. Iron Ore Production, Exports and Consumption, 1921-55.

XV. Nickel Production, Exports and Consumption, 1921-55.

XVI. World Mine Production of Nickel, 1880-1955.

XVII. World Production of Primary Nickel Metal, Oxides and Compounds.

XVIII. World Trade Pattern: Nickel, 1953.

XIX. Copper Production, Exports and Consumption, 1921-55.

XX. Zinc Production, Exports and Consumption, 1921-55.

XXI. Lead Production, Exports and Consumption, 1921-55.

XXII. Aluminum Production, Exports and Consumption, 1900-55.

XXIII. Platinum Group Metals, World Production, 1944-53.

XXIV. Canadian Silver Production by Ore Sources, 1936-55.

XXV. Asbestos Production, Exports and Consumption, 1926-55.

Table I

MINERAL PRICE TRENDS[a], NORTH AMERICA, 1901-55

(five-year averages)

5-year periods	All minerals	Mineral fuels	All metals excl. gold	Industrial minerals	Structural minerals
1901-05......	1.10	1.05	1.16	0.86	1.33
1906-10......	0.91	0.84	1.18	0.75	0.94
1911-15......	0.91	0.85	1.12	0.83	0.87
1916-20......	1.01	1.04	0.98	0.70	0.82
1921-25......	1.15	1.21	0.91	0.92	1.20
1926-30......	1.02	1.04	0.86	1.12	1.12
1931-35......	0.96	0.95	0.86	1.10	1.19
1936-40......	1.01	1.01	1.03	1.02	1.00
1941-45......	0.96	0.98	0.91	1.01	0.91
1946-50......	1.04	1.13	0.87	0.78	0.78
1951-55......	1.03	1.13	0.95	0.76	0.75

a Ores and concentrates only. The real price of primary manufactured minerals has shown a greater tendency to decline due to improvements in efficiency at the smelters and refiners etc.

Table II

GROSS VALUE OF MINE PRODUCTION IN CANADA, 1926-55

(in thousands of dollars)

Year	Total	Metal mining[a]	Fuel mining	Industrial mineral mining[b]	Structural material mining[c]	Value of output as percentage of total: Metal mining	Fuel mining	Industrial mineral mining	Structural material mining
1926	200,339	98,679	69,906	18,282	13,472	49.3	34.9	9.1	6.7
1927	199,369	92,754	71,329	19,280	16,006	46.5	35.8	9.7	8.0
1928	209,233	97,243	74,406	20,731	16,853	46.5	35.6	9.9	8.0
1929	235,026	114,967	76,501	23,129	20,429	48.9	32.5	9.8	8.7
1930	207,777	99,518	68,828	17,021	22,410	47.9	33.1	8.2	10.8
1931	184,897	99,752	54,120	12,380	18,645	53.9	29.3	6.7	10.1
1932	167,224	98,302	49,862	9,026	10,034	58.8	29.8	5.4	6.0
1933	179,558	112,075	48,498	11,109	7,876	62.4	27.0	6.2	4.4
1934	213,810	139,351	54,271	11,529	8,659	65.2	25.4	5.4	4.0
1935	213,330	139,189	50,569	11,876	11,696	65.2	23.7	5.6	5.5
1936	253,879	170,078	56,032	15,714	12,055	67.0	22.1	6.2	4.7
1937	326,914	227,121	61,019	21,342	17,432	69.5	18.7	6.5	5.3
1938	350,164	251,489	62,093	19,024	17,558	71.8	17.7	5.4	5.0
1939	383,076	273,746	67,742	23,870	17,718	71.4	17.7	6.2	4.6
1940	420,437	300,824	75,238	25,217	19,158	71.5	17.9	6.0	4.6
1941	458,715	325,300	81,696	33,342	18,377	70.9	17.8	7.3	4.0
1942	469,162	327,062	88,671	35,678	17,751	69.7	18.9	7.6	3.8
1943	437,050	292,497	88,340	39,243	16,970	66.9	20.2	9.0	3.9
1944	396,504	248,680	92,648	37,737	17,439	62.7	23.4	9.5	4.4
1945	379,977	231,671	89,230	40,341	18,735	61.0	23.5	10.6	4.9
1946	408,414	240,726	97,557	43,416	26,715	58.9	23.9	10.6	6.5
1947	510,691	311,445	105,196	54,471	39,579	61.0	20.6	10.7	7.7
1948	664,058	394,360	153,929	67,190	48,579	59.4	23.2	10.1	7.3
1949	720,269	414,629	189,589	64,342	51,709	57.6	26.3	8.9	7.2
1950	831,000	473,291	201,181	94,198	62,330	56.9	24.2	11.3	7.5
1951	968,583	549,498	232,096	113,712	73,277	56.7	24.0	11.7	7.6
1952	995,620	535,126	256,477	121,843	82,174	53.7	25.8	12.2	8.3
1953	1,004,185	486,048	314,059	119,980	84,098	48.4	31.3	11.9	8.4
1954	1,129,677	555,989	352,741	122,102	98,845	49.2	31.2	10.8	8.7
1955	1,357,857	695,700	410,245	140,400	111,512	51.2	30.2	10.3	8.2

a Includes gold, but excludes the value of all smelting and refining.
b Asbestos, gypsum, mica, salt, nepheline syenite, feldspar, quartz, ochres, talc, soapstone, etc.
c Includes sand, stone and gravel, but excludes clay products, cement and limes.
SOURCE: D.B.S. *Mineral Statistics.*

Table III

VALUE OF EXPORTS OF METALS, INDUSTRIAL MINERALS AND STRUCTURAL MATERIALS FROM CANADA, 1926-55[a]

(in thousands of dollars)

Year	Total[b]	Metals	Industrial minerals	Structural materials	Percentage of total mineral exports: Metals	Industrial minerals	Structural materials
1926	90,926	74,600	11,624	4,702	82.0	12.8	5.2
1927	95,047	79,164	11,653	4,230	83.3	12.3	4.4
1928	109,418	92,296	11,887	5,235	84.3	10.9	4.8
1929	138,354	118,728	13,723	5,903	85.8	9.9	4.3
1930	103,902	90,050	9,604	4,248	86.7	9.2	4.1
1931	63,482	54,468	5,856	3,158	85.8	9.2	5.0
1932	41,091	35,713	3,721	1,657	86.9	9.1	4.0
1933	72,726	64,159	5,821	2,746	88.2	8.0	3.8
1934	88,365	77,864	6,028	4,573	88.1	6.8	5.1
1935	116,701	104,269	7,755	4,677	89.3	6.7	4.0
1936	146,476	128,888	11,329	6,259	88.0	7.7	4.3
1937	210,819	187,206	15,670	7,943	88.8	7.4	3.8
1938	190,668	171,494	13,961	5,213	90.0	7.3	2.7
1939	199,481	176,090	16,916	6,475	88.3	8.5	3.2
1940	217,654	190,620	17,074	9,960	87.6	7.8	4.6
1941	284,329	249,412	21,850	13,067	87.7	7.7	4.6
1942	328,373	287,995	24,117	16,261	87.7	7.3	5.0
1943	333,616	291,233	24,406	17,977	87.3	7.3	5.4
1944	299,120	261,069	22,413	15,638	87.3	7.5	5.2
1945	328,655	291,041	24,297	13,317	88.6	7.4	4.0
1946	267,904	226,987	26,328	14,589	84.7	9.8	5.5
1947	339,862	287,165	36,200	16,497	84.5	10.7	4.8
1948	440,074	376,832	45,359	17,883	85.6	10.3	4.1
1949	483,175	427,260	40,381	15,534	88.4	8.4	3.2
1950	566,381	480,335	66,359	19,687	84.8	11.7	3.5
1951	704,448	592,144	85,177	27,177	84.1	12.1	3.8
1952	807,234	691,862	92,692	22,680	85.7	11.5	2.8
1953	839,762	712,499	91,835	35,428	84.8	10.9	4.2
1954	863,439	738,811	91,561	33,067	85.6	10.6	3.8
1955	1,079,582	939,888	106,655	33,039	87.1	9.9	3.0

a In the form of ores, concentrates and primary manufactures only.
b Excludes gold and the mineral fuels.
SOURCE: D.B.S. *Trade of Canada.*

Table IV

VALUE OF EXPORTS OF MINERAL ORES, CONCENTRATES AND PRIMARY MANUFACTURES FROM CANADA, 1926-55[a]

(in thousands of dollars)

Year	Total	Ores and concentrates	Primary manufactures	Percentage of total mineral exports: Ores and concentrates	Percentage of total mineral exports: Primary manufactures
1926	90,926	32,460	58,466	35.7	64.3
1927	95,047	30,381	64,666	32.0	68.0
1928	109,418	32,235	77,183	29.5	70.5
1929	138,354	34,985	103,369	25.3	74.7
1930	103,902	31,880	72,022	30.7	69.3
1931	63,482	17,893	45,589	28.2	71.8
1932	41,091	9,697	31,394	23.6	76.4
1933	72,726	15,790	56,936	21.7	78.3
1934	88,365	20,120	68,245	22.8	77.2
1935	116,701	21,800	94,901	18.7	81.3
1936	146,476	28,205	118,271	19.3	80.7
1937	210,819	44,160	166,659	20.9	79.1
1938	190,668	42,568	148,100	22.3	77.7
1939	199,481	49,068	150,413	24.6	75.4
1940	217,654	44,939	172,715	20.6	79.4
1941	284,329	51,448	232,881	18.1	81.9
1942	328,373	54,016	274,357	16.4	83.6
1943	333,616	55,098	278,518	16.5	83.5
1944	299,120	51,067	248,053	17.1	82.9
1945	328,655	50,051	278,604	15.2	84.8
1946	267,904	53,297	214,607	19.9	80.1
1947	339,862	80,783	259,079	23.8	76.2
1948	440,074	99,786	340,288	22.7	77.3
1949	483,175	137,864	345,311	28.5	71.5
1950	566,381	170,266	396,115	30.1	69.9
1951	704,448	221,467	482,981	31.4	68.6
1952	807,234	255,344	551,890	31.6	68.4
1953	839,762	282,374	557,388	33.6	66.4
1954	863,439	286,963	576,476	33.2	66.8
1955	1,079,582	358,674	720,908	33.2	66.8

a Excludes gold and the mineral fuels.

SOURCE: D.B.S. *Trade of Canada*.

Table V

VALUE OF EXPORTS OF NON-FERROUS METALS[a] FROM CANADA, 1926-55

(in thousands of dollars)

Year	Total	Ores and concentrates	Primary manufactures	Ores and concentrates as percentage of total	Primary manufactures as percentage of total
1926	70,425	19,941	50,484	28.3	71.7
1927	75,502	18,004	57,498	23.8	76.2
1928	88,206	19,169	69,037	21.7	78.3
1929	112,142	20,173	91,969	18.0	82.0
1930	86,869	21,581	65,288	24.8	75.2
1931	53,087	11,478	41,609	21.6	78.4
1932	34,722	5,875	28,847	16.9	83.1
1933	60,660	10,189	50,471	16.8	83.2
1934	75,125	14,182	60,943	18.9	81.1
1935	100,707	14,042	86,665	13.9	86.1
1936	123,717	16,799	106,918	13.6	86.4
1937	180,053	28,089	151,964	15.6	84.4
1938	166,612	28,024	138,588	16.8	83.2
1939	169,858	30,400	139,458	17.9	82.1
1940	176,749	25,185	151,564	14.2	85.8
1941	226,212	26,894	199,318	11.9	88.1
1942	265,689	27,845	237,844	10.5	89.5
1943	265,698	28,493	237,205	10.7	89.3
1944	241,884	26,446	215,438	10.9	89.1
1945	268,670	21,856	246,814	8.1	91.9
1946	209,656	19,990	189,666	9.5	90.5
1947	255,450	35,364	220,086	13.8	86.2
1948	344,597	44,961	299,636	13.0	87.0
1949	387,995	79,461	308,534	20.5	79.5
1950	426,585	85,898	340,687	20.1	79.9
1951	526,151	112,300	413,851	21.3	78.7
1952	609,930	135,592	474,338	22.2	77.8
1953	619,064	153,626	465,538	24.8	75.2
1954	665,363	150,443	514,920	22.6	77.4
1955	772,277	152,322	619,956	19.7	80.3

a Excludes gold, but includes aluminum.

SOURCE: D.B.S. *Trade of Canada.*

Table VI

VALUE OF EXPORTS OF NON-METALLIC MINERALS[a] FROM CANADA, 1926-55

(in thousands of dollars)

Year	Total	Ores and concentrates	Primary manufactures	Ores and concentrates as percentage of total	Primary manufactures as percentage of total
1926	16,326	12,512	3,814	76.6	23.4
1927	15,883	12,365	3,518	77.9	22.1
1928	17,122	13,053	4,069	76.2	23.8
1929	19,626	14,793	4,833	75.4	24.6
1930	13,852	10,296	3,556	74.3	25.7
1931	9,014	6,410	2,604	71.1	28.9
1932	5,378	3,820	1,558	71.0	29.0
1933	8,567	5,599	2,968	65.4	34.6
1934	10,601	5,926	4,675	55.9	44.1
1935	12,432	7,748	4,684	62.3	37.7
1936	17,588	11,397	6,191	64.8	35.2
1937	23,613	16,057	7,556	68.0	32.0
1938	19,174	14,543	4,631	75.8	24.2
1939	23,391	18,625	4,766	79.6	20.4
1940	27,034	18,830	8,204	69.7	30.3
1941	34,917	23,514	11,403	67.3	32.7
1942	40,378	25,115	15,263	62.2	37.8
1943	42,383	25,154	17,229	59.3	40.7
1944	38,051	23,468	14,583	61.7	38.3
1945	37,614	25,642	11,972	68.2	31.8
1946	40,917	28,954	11,963	70.8	29.2
1947	52,697	39,396	13,301	74.8	25.2
1948	63,242	49,524	13,718	78.3	21.7
1949	55,915	44,286	11,629	79.2	20.8
1950	86,046	71,058	14,988	82.6	17.4
1951	112,304	90,571	21,733	80.6	19.4
1952	115,372	97,419	17,953	84.4	15.6
1953	127,263	97,905	29,358	76.9	23.1
1954	124,628	96,801	27,827	77.7	22.3
1955	139,694	106,538	33,156	76.3	23.7

a Excluding the mineral fuels.

SOURCE: D.B.S. *Trade of Canada.*

Table VII

VALUE OF IMPORTS OF METALS, INDUSTRIAL MINERALS AND STRUCTURAL MATERIALS INTO CANADA, 1926-55[a]

(in thousands of dollars)

					Percentage of total mineral imports		
Year	Total[b]	Metals	Industrial minerals	Structural materials	Metals	Industrial minerals	Structural materials
1926........	26,885	20,434	6,004	447	76.0	22.3	1.7
1927........	33,633	25,716	7,484	433	76.5	22.2	1.2
1928........	38,507	29,015	8,655	837	75.3	22.5	2.2
1929........	45,184	33,501	10,217	1,466	74.2	22.6	3.2
1930........	29,626	20,443	7,752	1,431	69.0	26.2	4.8
1931........	17,254	10,926	5,547	781	63.3	32.1	4.5
1932........	9,754	5,179	4,279	296	53.1	43.9	3.0
1933........	11,074	6,142	4,635	297	55.5	41.8	2.7
1934........	17,783	11,215	6,003	565	63.1	33.7	3.2
1935........	24,229	17,234	6,189	806	71.1	25.6	3.3
1936........	22,452	13,740	7,675	1,037	61.2	34.2	4.6
1937........	33,597	20,431	11,711	1,455	60.8	34.9	4.3
1938........	22,784	13,415	8,490	879	58.9	37.3	3.8
1939........	29,939	18,496	10,144	1,299	61.8	33.9	4.3
1940........	51,610	38,641	11,211	1,758	74.9	21.7	3.4
1941........	64,618	50,879	11,189	2,550	78.7	17.3	3.9
1942........	62,396	46,130	13,530	2,736	73.9	21.7	4.4
1943........	71,910	54,898	13,872	3,140	76.3	19.3	4.4
1944........	47,056	29,719	14,425	2,912	63.2	30.6	6.2
1945........	55,429	38,436	14,186	2,807	69.3	25.6	5.1
1946........	63,537	42,162	18,705	2,670	66.4	29.4	4.2
1947........	82,544	58,324	20,147	4,073	70.7	24.4	4.9
1948........	101,257	77,122	19,068	5,067	76.2	18.8	5.0
1949........	100,041	74,603	21,079	4,359	74.6	21.1	4.3
1950........	124,578	92,724	26,366	5,488	74.4	21.2	4.4
1951........	167,955	129,642	29,480	8,833	77.2	17.6	5.2
1952........	178,943	140,059	31,581	7,303	78.3	17.6	4.1
1953........	147,284	107,071	31,711	8,502	72.7	21.5	5.8
1954........	124,021	85,765	29,995	8,261	69.1	24.2	6.7
1955........	157,478	112,448	34,960	10,070	71.4	22.2	6.4

a In the form of ores, concentrates and primary manufactures only.

b Excludes gold and the mineral fuels.

SOURCE: D.B.S. *Trade of Canada.*

Table VIII

VALUE OF IMPORTS OF MINERAL ORES, CONCENTRATES AND PRIMARY MANUFACTURES INTO CANADA, 1926-55[a]

(in thousands of dollars)

				Percentage of total mineral imports	
Year	Total	Ores and concentrates	Primary manufactures	Ores and concentrates	Primary manufactures
1926	26,885	13,359	13,526	49.7	50.3
1927	33,633	17,337	16,296	51.5	48.5
1928	38,507	17,615	20,892	45.7	54.3
1929	45,184	18,201	26,983	40.3	59.7
1930	29,626	15,020	14,606	50.7	49.3
1931	17,254	10,879	6,375	63.1	36.9
1932	9,745	6,557	3,188	67.3	32.7
1933	11,074	7,052	4,022	63.7	36.3
1934	17,783	9,281	8,502	52.2	47.8
1935	24,229	11,455	12,774	47.3	52.7
1936	22,452	12,355	10,097	55.0	45.0
1937	33,597	18,885	14,712	56.2	43.8
1938	22,784	12,253	10,531	53.8	46.2
1939	29,939	15,630	14,309	52.2	47.8
1940	51,610	23,482	28,128	45.5	54.5
1941	64,618	31,083	33,535	48.1	51.9
1942	62,396	36,166	26,230	58.0	42.0
1943	71,910	48,982	22,928	68.1	31.9
1944	47,056	34,536	12,520	73.3	26.6
1945	55,429	35,182	20,247	63.5	36.5
1946	63,537	33,147	30,390	52.2	47.8
1947	82,544	50,466	32,078	61.1	38.9
1948	101,257	54,765	46,492	54.1	45.9
1949	100,041	50,700	49,341	50.7	49.3
1950	124,578	65,034	59,544	52.2	47.8
1951	167,955	89,861	78,094	53.5	46.5
1952	178,943	97,347	81,596	54.4	45.6
1953	147,284	84,054	63,230	57.1	42.9
1954	124,021	71,517	52,504	57.7	42.3
1955	157,478	94,027	63,451	59.7	40.3

a Excludes gold and the mineral fuels.
SOURCE: D.B.S. *Trade of Canada*.

Table IX

VALUE OF IMPORTS OF NON-FERROUS METALS[a] INTO CANADA, 1926-55

(in thousands of dollars)

Year	Total	Ores and concentrates	Primary manufactures	Ores and concentrates as percentage of total	Primary manufactures as percentage of total
1926	15,054	4,827	10,227	32.1	67.9
1927	19,716	8,496	11,220	43.1	56.9
1928	20,039	6,721	13,318	33.5	66.5
1929	24,279	4,983	19,296	20.5	79.5
1930	14,589	4,647	9,942	31.9	68.1
1931	7,508	3,832	3,676	51.0	49.0
1932	4,300	2,295	2,005	53.4	46,6
1933	5,023	2,437	2,586	48.5	51.5
1934	8,125	2,768	5,357	34.1	65.9
1935	12,935	3,726	9,209	28.8	71.2
1936	10,061	4,181	5,880	41.6	58.4
1937	12,536	6,622	5,914	52.8	47.2
1938	9,009	4,647	4,362	51.6	48.4
1939	11,355	5,328	6,027	46.9	53.1
1940	23,816	9,378	14,438	39.4	60.6
1941	27,906	14,030	13,876	50.3	49.7
1942	25,512	18,266	7,246	71.6	28.4
1943	33,873	27,880	5,993	82.3	17.7
1944	19,062	15,024	4,038	78.8	21.2
1945	25,956	14,694	11,262	56.6	43.4
1946	32,226	12,799	19,427	39.7	60.3
1947	38,958	20,265	18,693	52.0	48.0
1948	45,445	22,174	23,271	48.8	51.2
1949	48,147	21,612	26,535	44.9	55.1
1950	65,796	28,084	37,712	42.7	57.3
1951	87,469	41,926	45,543	47.9	52.1
1952	90,115	46,996	43,119	52.1	47.9
1953	70,041	29,783	40,258	42.5	57.5
1954	58,366	26,410	31,956	45.2	54.8
1955	59,874	34,901	24,973	58.3	41.7

a Excludes gold but includes aluminum.

SOURCE: D.B.S. *Trade of Canada.*

Table X

VALUE OF IMPORTS OF NON-METALLIC MINERALS INTO CANADA, 1926-55[a]

Year	Total	Ores and concentrates	Primary manufactures	Percentage of total non-metallic imports: Ores and concentrates	Percentage of total non-metallic imports: Primary manufactures
1926	6,451	5,678	773	88.0	12.0
1927	7,917	5,965	1,952	75.3	24.7
1928	9,492	6,569	2,923	69.2	30.8
1929	11,683	8,192	3,491	70.1	29.9
1930	9,183	7,049	2,134	76.8	23.2
1931	6,328	5,329	999	84.2	15.8
1932	4,566	4,078	488	89.3	10.7
1933	4,932	4,214	718	85.4	14.6
1934	6,568	4,686	1,882	71.3	28.7
1935	6,995	4,769	2,226	68.2	31.8
1936	8,712	5,540	3,172	63.6	36.4
1937	13,166	7,542	5,624	57.3	42.7
1938	9,369	4,776	4,593	51.0	49.0
1939	11,443	6,123	5,320	53.5	46.5
1940	12,969	8,591	4,378	66.2	33.8
1941	13,739	9,918	3,821	72.2	27.8
1942	16,266	11,670	4,596	71.7	28.3
1943	17,012	12,046	4,966	70.8	29.2
1944	17,337	12,118	5,219	69.9	30.1
1945	16,993	11,892	5,101	70.0	30.0
1946	21,375	13,881	7,494	64.9	35.1
1947	24,220	17,484	6,736	72.2	27.8
1948	24,135	17,084	7,051	70.8	29.2
1949	25,438	17,031	8,407	67.0	33.0
1950	31,854	20,148	11,706	63.3	36.7
1951	38,313	25,264	13,049	65.9	34.1
1952	38,884	23,832	15,052	61.3	38.7
1953	40,213	26,077	14,136	64.8	35.2
1954	38,256	24,692	13,564	64.5	35.5
1955	45,030	27,563	17,467	61.2	38.8

a Excludes the mineral fuels.
SOURCE: D.B.S. *Trade of Canada.*

Table XI

VALUE OF THE DOMESTIC SUPPLY OF MINERAL ORES, CONCENTRATES AND PRIMARY MANUFACTURES IN CANADA, 1926-55[a]

(in thousands of dollars)

Year	Production	Imports	Exports	Domestic supply	Imports as a percentage of domestic supply
1926....	144,622	26,885	90,926	80,581	33.4
1927....	154,438	33,633	95,047	93,024	36.2
1928....	177,930	38,507	109,418	107,019	36.0
1929....	205,677	45,184	138,354	112,507	40.2
1930....	181,875	29,626	103,902	107,599	27.5
1931....	129,278	17,254	63,482	83,050	20.8
1932....	76,741	9,745	41,091	45,395	21.5
1933....	95,898	11,074	72,726	34,246	32.3
1934....	127,536	17,783	88,365	56,954	31.2
1935....	150,078	24,229	116,701	57,606	42.1
1936....	182,394	22,452	146,476	58,370	38.5
1937....	266,108	33,597	210,819	88,886	37.8
1938....	237,207	22,784	190,668	69,323	32.9
1939....	249,969	29,939	199,481	80,427	37.2
1940....	288,092	51,610	217,654	122,048	42.3
1941....	353,362	64,618	284,329	133,651	48.3
1942....	409,802	62,396	328,373	143,825	43.4
1943....	461,554	71,910	333,616	199,848	36.0
1944....	422,471	47,056	299,120	170,407	27.6
1945....	370,212	55,429	328,655	96,986	57.2
1946....	347,062	63,537	267,904	142,695	44.5
1947....	500,501	82,544	339,862	243,183	33.9
1948....	631,316	101,257	440,074	282,499	34.6
1949....	674,676	100,041	483,175	291,542	34.3
1950....	789,172	124,578	566,381	347,369	35.9
1951....	992,039	167,955	704,448	455,546	36.9
1952....	1,041,430	178,943	807,234	413,139	43.3
1953....	1,073,932	147,284	839,762	381,454	38.6
1954....	1,192,522	124,021	863,439	453,104	27.4
1955....	1,452,042	157,478	1,079,582	529,939	29.7

a Excludes gold and the mineral fuels.

SOURCE: D.B.S. *Trade of Canada* and *Mineral Statistics.*

Table XII

EMPLOYMENT IN MINING, CANADA, 1926-55

(by number of employees)

						Employment as percentage of total			
Year	Total all mines	Metal mining	Fuel mining	Industrial mineral mining	Structural material mining	Metal mining	Fuel mining	Industrial mineral mining	Structural material mining
1926	63,864	17,516	30,256	5,910	10,182	27.4	47.4	9.3	15.9
1927	68,825	18,672	31,895	6,054	12,204	27.1	46.3	8.8	17.7
1928	73,102	21,056	33,034	6,052	12,960	28.8	45.2	8.3	17.7
1929	72,145	21,997	32,982	5,373	11,793	30.5	45.7	7.4	16.3
1930	77,525	23,006	33,913	6,167	14,439	29.7	43.7	8.0	18.6
1931	59,071	17,574	30,761	3,314	7,422	29.7	52.1	5.6	12.6
1932	52,494	16,588	28,966	2,688	4,252	31.6	55.2	5.1	8.1
1933	54,226	19,083	27,460	3,072	4,611	35.2	50.6	5.7	8.5
1934	62,038	25,845	28,458	3,737	3,998	41.7	45.9	6.0	6.4
1935	67,904	29,659	28,857	3,898	5,490	43.7	42.5	5.7	8.1
1936	77,358	36,440	30,045	4,723	6,150	47.1	38.8	6.1	7.9
1937	89,602	43,476	30,850	6,294	8,982	48.5	34.4	7.0	10.0
1938	90,344	43,703	30,934	5,933	9,774	48.4	34.2	6.6	10.8
1939	91,207	45,594	30,242	6,175	9,196	50.0	33.2	6.7	10.1
1940	90,849	46,885	30,364	6,471	7,129	51.6	33.4	7.1	7.8
1941	91,992	48,277	30,335	7,370	6,010	52.5	33.0	8.0	6.5
1942	86,095	43,023	30,117	8,117	4,838	50.0	35.0	9.4	5.6
1943	81,111	37,575	30,754	7,989	4,793	46.3	37.9	9.9	5.9
1944	76,682	34,559	29,953	8,233	3,937	45.1	39.1	10.7	5.1
1945	74,618	32,913	29,159	8,318	4,228	44.1	39.1	11.1	5.7
1946	78,771	35,445	28,705	9,108	5,513	45.0	36.4	11.6	7.0
1947	80,830	39,334	25,307	9,593	6,596	48.7	31.3	11.9	8.1
1948	86,564	41,890	27,791	9,604	7,279	48.4	32.1	11.1	8.4
1949	90,973	46,181	28,595	8,606	7,591	50.8	31.4	9.5	8.3
1950	93,948	47,697	28,453	10,116	7,682	50.8	30.2	10.8	8.2
1951	99,293	52,271	28,490	10,611	7,921	52.6	28.7	10.7	8.0
1952	102,696	55,338	28,029	11,247	8,082	53.9	27.3	11.0	7.9
1953	99,756	51,711	28,766	11,099	8,180	51.8	28.8	11.1	8.2
1954	95,881	51,599	24,807	10,892	8,583	53.8	25.9	11.4	8.9
1955	98,457	53,778	25,125	11,086	8,468	54.6	25.5	11.3	8.6

SOURCE: D.B.S. *Mineral Statistics of Canada.*

Table XIII

CANADIAN MINERAL INDUSTRY, SALARIES AND WAGES AS A PERCENTAGE OF GROSS AND NET VALUE OF PRODUCTION[a], FIVE-YEAR PERIODS, 1926-55

Period	Gross value of production	Net value of production	Salaries and wages	Salaries and wages as % of Gross	Salaries and wages as % of Net
	(in thousands of dollars)				
Metal mines					
1926-30	435,992	413,568	170,864	39.2	41.3
1931-35	528,690	485,370	170,924	32.3	35.2
1936-40	1,223,258	944,495	368,353	30.1	39.0
1941-45	1,425,212	1,085,528	403,548	28.3	37.2
1946-50	1,834,450	1,377,707	563,281	30.7	40.9
1951-55	2,796,426	1,972,523	966,377	34.6	49.0
Industrial minerals					
1926-30	98,443	89,199	33,133	33.7	37.1
1931-35	55,918	47,507	15,202	27.2	32.0
1936-40	105,170	80,742	32,171	30.6	39.8
1941-45	186,341	145,986	55,813	30.0	38.2
1946-50	323,616	255,240	98,026	30.3	38.4
1951-55	618,005	498,684	184,198	29.8	36.9
Structural materials					
1926-30	286,176	246,767	82,524	28.8	33.4
1931-35	140,563	121,793	38,709	27.5	31.8
1936-40	173,606	142,890	51,582	29.7	36.1
1941-45	230,685	174,467	63,360	27.5	36.3
1946-50	514,010	398,285	129,973	25.3	32.6
1951-55	960,342	765,785	234,220	24.4	30.6
Total mining excluding smelting and refining[b]					
1926-30	819,612	749,534	286,521	35.0	38.2
1931-35	725,171	654,670	224,835	31.0	34.3
1936-40	1,502,034	1,168,127	452,106	30.1	38.7
1941-45	1,842,238	1,405,981	522,721	28.4	37.2
1946-50	2,672,076	2,031,224	791,280	29.6	39.0
1951-55	4,374,773	3,236,992	1,384,795	31.7	42.7
Smelting and refining					
1926-30	294,563	264,250	61,502	20.9	23.3
1931-35	420,971	277,322	54,173	12.9	19.5
1936-40	1,403,274	438,293	93,025	6.6	21.2
1941-45	2,168,036	570,676	191,706	8.8	33.6
1946-50	2,603,208	716,816	237,574	9.1	33.1
1951-55	4,703,603	1,635,944	478,770	10.2	29.3

a Excludes mineral fuels.

b Smelting and refining excluded from total to avoid double counting.

SOURCE: D.B.S., *Mineral Statistics of Canada.*

Table XIV

IRON ORE PRODUCTION, EXPORTS AND CONSUMPTION, 1921-55

Year	Canada					
	Production[a]	Exports	Consumption	Production as % of world consumption	World[b] consumption	North American[c] consumption
	(In millions of long tons)				(In millions of long tons)	
1921....	0.1	—	1.2	0.1	72.0	30.3
1922....	—	—	0.7	—	96.0	48.1
1923....	—	—	1.7	—	134.0	73.0
1924....	—	—	1.1	—	128.0	55.0
1925....	—	—	1.1	—	143.3	65.4
1926....	—	—	1.4	—	147.0	69.7
1927....	—	—	1.3	—	162.1	65.5
1928....	—	—	1.9	—	164.0	68.3
1929....	—	—	2.0	—	188.5	77.1
1930....	—	—	1.4	—	168.6	56.6
1931....	—	—	0.8	—	111.2	31.3
1932....	—	—	0.3	—	69.0	13.5
1933....	—	—	0.4	—	83.6	22.3
1934....	—	—	0.8	—	109.8	27.3
1935....	—	—	1.1	—	127.9	36.6
1936....	—	—	1.3	—	161.7	53.1
1937....	—	—	1.7	—	202.1	64.3
1938....	—	—	1.3	—	153.4	33.7
1939....	0.1	—	1.4	0.1	183.4	54.8
1940....	0.4	0.2	2.2	0.2	193.8	82.5
1941....	0.5	0.3	2.6	0.2	207.9	97.0
1942....	0.5	0.3	3.4	0.2	207.7	107.4
1943....	0.6	0.3	3.1	0.3	214.0	103.6
1944....	0.5	0.3	3.3	0.3	199.2	103.2
1945....	1.0	0.7	2.8	0.6	156.0	91.0
1946....	1.4	1.0	2.4	0.9	152.8	74.6
1947....	1.7	1.6	3.4	0.9	186.6	99.5
1948....	1.2	1.0	3.6	0.6	216.5	104.1
1949....	3.3	2.3	3.6	1.5	219.2	92.8
1950....	3.2	2.0	3.9	1.3	241.9	110.5
1951....	4.2	2.9	4.4	1.5	283.8	119.2
1952....	4.7	3.4	4.6	1.7	284.1	105.2
1953....	5.8	4.3	4.9	1.8	314.1	129.7
1954....	6.6	4.8	3.5	2.4	279.8	96.8
1955....	14.5	13.0	5.6	4.3	340.4	129.5

a No Canadian production 1922-38.

b Source: American Iron and Steel Institute.

c U.S. consumption (Source: U.S. Bureau of Mines) plus Canadian consumption.

Table XV

NICKEL PRODUCTION, EXPORTS AND CONSUMPTION, 1921-55

Year	Canada: Production	Canada: Exports	Canada: Consumption[a]	Canada: Production as % of world consumption	World consumption	North American consumption
	(in thousands of short tons)					
1921....	10	6	—	87.3	11	—
1922....	9	21	1	67.7	13	—
1923....	31	29	—	91.8	34	—
1924....	35	31	—	89.2	39	—
1925....	37	36	1	90.0	41	—
1926....	33	32	1	88.9	37	20
1927....	33	35	1	87.9	38	19
1928....	48	49	1	88.0	55	31
1929....	55	55	1	88.9	62	42
1930....	52	46	1	86.6	60	25
1931....	33	32	—	82.0	40	15
1932....	15	16	—	63.3	24	9
1933....	42	44	1	81.6	51	22
1934....	64	59	—	81.4	79	20
1935....	69	71	1	83.5	83	34
1936....	85	87	1	86.6	98	46
1937....	113	111	1	85.2	132	47
1938....	105	99	1	82.9	127	23
1939....	113	117	1	83.8	135	53
1940....	123	125	2	79.7	154	78
1941....	141	138	4	78.8	179	110[b]
1942....	143	139	5	82.0	174	117[b]
1943....	144	136	3	78.3	184	125[b]
1944....	137	133	2	79.4	173	119[b]
1945....	123	108	2	76.6	160	99
1946....	96	112	2	71.2	135	82
1947....	119	117	2	77.0	154	83
1948....	132	132	2	79.3	166	95
1949....	129	127	2	79.9	161	70
1950....	124	122	2	78.3	158	101
1951....	138	131	3	78.8	175	89
1952....	141	142	2	74.0	190	104
1953....	144	146	2	64.2	224	107
1954....	161	159	3	67.2	240	97
1955....	175	174	4	64.3	272[c]	113[c]

a Less than 500 short tons were consumed in the Canadian manufacturing industry for the years 1921, 1923, 1924, 1931, 1932 and 1934.

b Estimated.

c Preliminary (American Bureau of Metal Statistics).

SOURCE: *Statistics Relating to the Canadian Mineral Industry* prepared by Mineral Resources Division, Department of Mines and Technical Surveys.

Table XVI

WORLD MINE PRODUCTION OF NICKEL, 1880-1955

(thousand short tons recoverable nickel content)

Year	Canada	N. Caledonia	Cuba	U.S.	Others	Free world	Russia etc. A	Russia etc. B
1880........	—	0.3	—	0.1	0.2	0.6	—	
1890........	0.7	2.2	—	0.1	0.1	3.1	—	
1903........	6.3	4.6	—	—	0.4	11.3	—	
1918........	46.3	3.0	—	0.4	2.8	52.5	—	
1922........	8.8	3.9	—	0.2	0.1	13.0	—	
1929........	51.9	4.8	—	0.3	5.1	62.1	—	
1932........	15.2	5.5	—	0.2	2.0	22.9	1.1	
1939........	113.1	11.7	—	0.4	7.4	132.6	5.5	
1943........	144.0	8.1	2.7	0.6	16.8	172.2	12.3	
1946........	96.1	3.2	12.4	0.4	1.3	113.4	22.0	16.7
1948........	131.7	3.8	—	0.9	0.5	136.9	27.5	19.6
1950........	123.7	4.7	—	0.9	0.9	130.2	32.0	22.7
1951........	137.9	7.4	—	0.8	1.3	147.4	36.5	25.0
1952........	140.6	11.6	8.9	0.6	1.9	163.6	41.0	28.4
1953........	143.7	18.7	13.8	0.6	2.3	179.1	44.0	28.6
1954........	161.5	(16.0)	14.5	2.6	2.3	196.9	47.0	
1955........	173.5	(18.0)	(15.0)	4.3	(2.7)	213.5	47.0	

SOURCES: 1880-1939—*International Control in Non-Ferrous Metals*, A. Skelton *et al.* *Materials Survey—Nickel*, U.S. Bureau of Mines.

1943-55—*Metallgesellschaft*, American Bureau of Metal Statistics, Company Reports.

Russia A—American Bureau of Metal Statistics.

Russia B—*Metallgesellschaft*.

Table XVII

WORLD PRODUCTION OF PRIMARY NICKEL METAL, OXIDES AND COMPOUNDS

(estimated—thousand short tons nickel content)

Year	Canada	U.K.	Norway	U.S.[a]	Cuba	France N. Caledonia	Germany and others	Free world	Russia etc. A	Russia etc. B
1903	—	1.9	0.1	5.6	—	1.7	1.7	11.0	—	
1917	0.4	5.5	0.4	36.0	—	2.1	2.5	46.9	—	
1921	3.3	2.8	—	1.1	—	1.1	0.6	8.9	—	
1929	41.1	14.0	0.4	8.6	—	2.2	5.0	71.3	—	
1932	7.6	3.7	3.0	2.8	—	2.5	2.5	22.1	1.2	
1939	66.0	(26.0)	(9.5)	(8.0)	—	(7.0)	(10.0)	126.5	5.5	
1943	107.0	(17.0)	—	(26.0)	2.7	—	(17.0)	169.7	12.3	
1946	65.6	(10.0)	(8.0)	(12.0)	12.4	(2.0)	(1.0)	111.0	22.0	16.7
1948	81.0	19.2	9.2	(20.0)	—	(3.0)	(1.0)	133.4	27.5	19.6
1950	69.7	23.4	11.0	(22.0)	—	(6.0)	(1.0)	133.1	32.0	22.7
1951	77.9	26.1	12.2	(18.0)	—	(6.0)	(2.0)	142.2	36.5	25.0
1952	78.0	26.7	13.4	(21.0)	8.9	(10.0)	(3.0)	161.0	41.0	28.4
1953	84.0	26.8	16.4	(21.0)	13.8	(12.0)	(5.0)	179.0	44.0	28.6
1954	94.2	(27.0)	(19.6)	(22.5)	14.5	(12.0)	(7.0)	196.8	47.0	
1955	110.2	(27.0)	(20.7)	(22.0)	(15.0)	(12.0)	(9.0)	215.9	47.0	

a United States: Since 1917 production largely in form of Monel nickel-copper alloy, made directly from matte. Recovery from scrap, not included, is about 8,000 tons annually.

SOURCES: 1903-32, *International Control in Non-Ferrous Metals*, A. Skelton *et al*; 1932-55, based on *Trade of Canada*, *Quin's Metal Handbook*, *Metallgesellschaft*; Russia: A—U.S. Bureau of Mines; B—*Metallgesellschaft*.

Table XVIII

WORLD TRADE PATTERN: NICKEL, 1953

(thousand short tons nickel content: plus is export, minus is import)

Country	Ore and matte	Oxide	Metal (incl. alloy) +	Metal (incl. alloy) —	Net Total	Net trade—Percentage +	Net trade—Percentage —
Canada	+63.9	+ 1.3	79.9	3.0	+142.1	81.2	
Norway	—16.4	—	15.4	0.4	— 1.4		0.8
United Kingdom	—29.1	— 0.2	18.4	11.9	— 22.8		13.6
South Africa	+ 1.7	—	—	—	+ 1.7	1.0	
Germany	— 0.2	—	0.4	7.9	— 7.7		4.6
Finland	+ 0.5	—	—	0.2	+ 0.3	0.1	
Sweden	—	—	—	3.2	— 3.2		1.9
Other Europe	—	—	—	4.0	— 4.0		2.4
United States	—20.2	—15.0	10.6	85.6	—110.2		65.7
Cuba	—	+13.8	—	—	+ 13.8	7.9	
New Caledonia	+17.0	—	—	—	+ 17.0	9.7	
France	— 7.5	—	0.2	2.2	— 9.5		5.7
Japan	— 9.5	—	0.7	0.1	— 8.9		5.3
World							
Exports (+)	83.1	15.1	125.6	—	174.9	100	—
Imports (—)	82.9	15.2	—	118.5	167.7	—	100

SOURCES: *Trade of Canada, Quin's Metal Handbook;* Colonial Geological Survey, *Summary* 1948-53.

Table XIX

COPPER PRODUCTION, EXPORTS AND CONSUMPTION, 1921-55

Year	Canada					
	Production	Exports	Consumption	Production as % of world consumption	World consumption	North American consumption
	(in thousands of short tons)					
1921....	24	21	14	3.9	614	319
1922....	21	30	11	2.2	973	459
1923....	43	46	12	3.1	1,403	662
1924....	52	49	17	3.5	1,501	694
1925....	56	56	13	3.4	1,649	714
1926....	66	56	18	3.9	1,668	803
1927....	70	64	17	4.2	1,678	729
1928....	101	91	19	5.4	1,892	823
1929....	124	118	23	5.8	2,147	912
1930....	152	115	20	8.6	1,771	653
1931....	146	96	17	9.5	1,543	468
1932....	124	131	26	10.9	1,137	286
1933....	150	102	32	13.0	1,151	371
1934....	182	125	43	12.9	1,412	366
1935....	210	178	43	12.7	1,647	484
1936....	211	178	52	11.1	1,898	708
1937....	265	190	58	10.3	2,562	753
1938....	286	252	54	12.6	2,269	461
1939....	304	242	57	12.6	2,411	772
1940....	328	223	107	12.2	2,682	1,116
1941....	322	186	142	11.4	2,818	1,784
1942....	302	139	183	10.1	2,982	1,791
1943....	288	105	176	9.6	2,981	1,678
1944....	274	163	122	9.9	2,772	1,626
1945....	238	149	90	10.0	2,373	1,505
1946....	184	119	81	9.0	2,035	1,472
1947....	226	117	109	9.2	2,448	1,395
1948....	241	195	107	9.5	2,541	1,321
1949....	264	164	101	10.6	2,475	1,173
1950....	264	167	107	9.6	2,761	1,554
1951....	270	139	134	9.3	2,893	1,438
1952....	258	148	130	8.6	3,009	1,490
1953....	253	183	109	8.2	3 072	1,544
1954....	303	204	102	9.8	3,095	1,339
1955....	325	195	137	9.6	3,383	1,583

SOURCE: *Statistics Relating to the Canadian Mineral Industry*, prepared for the Commission by Mineral Resources Division, Dept. of Mines and Technical Surveys.

Table XX

ZINC PRODUCTION, EXPORTS AND CONSUMPTION, 1921-55

	Canada					
Year	Production	Exports	Consumption	Production as % of world consumption	World consumption	North American consumption
			(in thousands of short tons)			
1921....	27	24	—	4.5	592	—
1922....	28	18	—	3.2	892	—
1923....	30	20	—	2.9	1,026	—
1924....	50	44	—	4.6	1,080	—
1925....	55	48	—	4.3	1,267	—
1926....	75	63	—	4.2	1,768	—
1927....	83	66	—	4.6	1,787	—
1928....	92	75	—	5.2	1,762	—
1929....	99	80	—	6.2	1,596	—
1930....	134	99	—	8.7	1,533	—
1931....	119	119	—	10.8	1,097	—
1932....	86	88	—	10.0	862	—
1933....	100	91	—	9.2	1,081	—
1934....	149	139	—	11.6	1,290	—
1935....	160	145	15	10.9	1,474	492
1936....	167	160	19	10.3	1,610	593
1937....	185	167	23	10.3	1,790	637
1938....	191	155	19	11.1	1,725	432
1939....	197	177	23	11.0	1,800	599
1940....	212	201	37	11.9	1,784	721
1941....	256	196	57	13.7	1,875	824
1942....	290	228	84	14.6	1,982	759
1943....	305	241	80	15.1	2,025	849
1944....	275	209	69	15.4	1,790	909
1945....	259	214	61	18.5	1,401	864
1946....	235	203	46	13.5	1,742	803
1947....	208	178	51	10.7	1,946	778
1948....	234	199	47	11.5	2,044	803
1949....	288	275	46	13.8	2,089	703
1950....	313	276	54	13.4	2,341	955
1951....	341	301	61	13.5	2,518	947
1952....	372	349	52	13.4	2,775	850
1953....	402	351	51	14.5	2,776	987
1954....	377	386	47	13.5	2,783	923
1955....	427	404	58	14.6	2,927	1,172

SOURCE: *Statistics Relating to the Canadian Mineral Industry*, prepared for the Commission by Mineral Resources Division, Dept. of Mines and Technical Surveys.

Table XXI

LEAD PRODUCTION, EXPORTS AND CONSUMPTION, 1921-55

Year	Canada					
	Production	Exports	Consumption	Production as % of world consumption	World consumption	North American consumption
	(in thousands of short tons)					
1921....	33	21	—	3.4	974	—
1922....	47	24	—	4.0	1,179	—
1923....	56	35	—	4.2	1,313	—
1924....	88	76	—	6.0	1,459	—
1925....	127	99	—	7.7	1,639	—
1926....	142	108	—	8.0	1,770	—
1927....	156	126	—	8.4	1,857	—
1928....	169	135	—	9.2	1,840	—
1929....	163	122	—	8.3	1,967	—
1930....	166	116	29	8.9	1,867	604
1931....	134	110	22	8.8	1,526	420
1932....	128	109	15	10.0	1,276	290
1933....	133	146	15	10.5	1,274	328
1934....	173	153	18	11.9	1,451	351
1935....	170	147	22	11.1	1,523	409
1936....	192	165	23	11.8	1,626	512
1937....	206	185	25	11.2	1,847	576
1938....	210	159	26	11.2	1,870	426
1939....	194	185	27	10.2	1,907	568
1940....	236	161	38	12.1	1,943	658
1941....	230	191	58	12.1	1,894	994
1942....	256	217	58	13.6	1,879	813
1943....	222	160	53	14.0	1,587	899
1944....	152	112	52	11.4	1,339	905
1945....	174	115	62	13.8	1,258	838
1946....	177	110	63	14.4	1,232	605
1947....	162	132	64	11.1	1,453	808
1948....	167	109	60	10.7	1,570	805
1949....	160	133	51	9.5	1,690	630
1950....	166	134	52	9.0	1,837	937
1951....	158	125	60	8.5	1,854	738
1952....	169	154	63	8.4	2,002	845
1953....	194	165	68	9.7	1,997	852
1954....	219	176	68	10.4	2,110	832
1955....	203	151	66	9.3	2,178	930

SOURCE: *Statistics Relating to the Canadian Mineral Industry*, prepared for the Commission by Mineral Resources Division, Dept. of Mines and Technical Surveys.

Table XXII

ALUMINUM PRODUCTION, EXPORTS AND CONSUMPTION, 1900-55

Year	Canada					
	Production	Exports[a]	Consumption[b]	Production as % of world consumption	World consumption	North American[b] consumption
	(in thousands of short tons)					
1900....	—	—	—	—	8	—
1901....	—	—	—	1.2	8	—
1902....	1	—	—	11.1	9	—
1903....	1	—	—	10.0	9	—
1904....	1	—	—	11.0	10	—
1905....	1	—	—	10.0	13	—
1906....	2	—	—	14.4	16	—
1907....	3	—	—	13.6	22	—
1908....	1	—	—	2.5	20	—
1909....	3	—	—	8.8	34	—
1910....	5	—	—	10.0	48	—
1911....	5	—	—	9.6	50	—
1912....	6	—	—	8.9	67	—
1913....	7	—	—	9.7	80	—
1914....	7	—	—	7.4	99	—
1915....	9	—	—	9.9	93	—
1916....	11	—	—	7.8	135	—
1917....	11	—	—	6.2	176	—
1918....	12	—	—	6.2	190	—
1919....	11	—	—	6.6	164	—
1920....	11	—	—	7.9	141	—
1921....	3	3	—	3.9	83	—
1922....	6	7	—	6.3	102	—
1923....	12	8	—	7.9	153	—
1924....	14	11	—	7.3	187	—
1925....	16	12	—	7.8	200	—
1926....	20	13	—	9.0	216	—
1927....	41	26	—	18.8	220	—
1928....	41	20	—	14.7	282	—
1929....	32	37	—	10.4	305	—
1930....	38	22	—	13.0	294	—
1931....	34	11	—	13.5	253	—
1932....	20	9	—	11.7	169	—
1933....	18	17	—	11.4	156	—
1934....	17	21	—	9.3	188	—
1935....	23	30	9	8.1	286	105
1936....	30	29	9	7.5	395	147
1937....	50	49	11	9.4	531	179
1938....	71	65	9	11.2	638	99
1939....	83	71	11	10.4	793	178
1940....	109	87	18	12.0	913	245
1941....	214	193	20	17.8	1,204	323
1942....	341	315	33	22.3	1,526	621
1943....	496	375	40	23.1	2,145	917
1944....	462	295	38	24.1	1,915	783
1945....	216	382	41	22.5	958	737
1946....	193	187	34	22.2	870	610
1947....	299	214	50	25.1	1,190	622
1948....	367	327	64	26.3	1,395	749
1949....	370	297	59	25.7	1,440	695
1950....	397	336	64	24.1	1,650	962

Table XXII (Cont'd.)

1951....	447	354	86	22.6	1,975	1,062
1952....	500	413	90	22.1	2,260	1,163
1953....	548	460	92	20.2	2,716	1,634
1954....	561	469	80	18.9	2,975	1,775
1955....	584	507	92	18.0	3,240	2,154

a Exports figures not available 1900-20.

b Consumption figures not available 1900-34

SOURCE: *Statistics Relating to the Canadian Mineral Industry*, prepared for the Commission by Mineral Resources Division, Dept. of Mines and Technical Surveys.

Table XXIII

PLATINUM GROUP METALS, WORLD PRODUCTION, 1944-53

(1944-48 (average) and 1949-53, in troy ounces)

Country	1944-48 (ave.)	1949	1950	1951	1952	1953
Australia:						
Placer platinum................	1	—	16	8	—	—
Placer osmiridium..............	100	39	48	33	51	59
Belgian Congo:						
Palladium from refineries........	42	106	—	—	—	—
Canada:						
Platinum: Placer and from refining nickel-copper matte...........	140,700	153,784	124,571	153,483	122,317	134,108
Other platinum-group metals from refining nickel-copper matte	175,569	182,233	148,741	164,905	157,407	161,550
Colombia:						
Placer platinum................	38,872	20,797	26,445	32,000	33,700	28,977
Ethiopia:						
Placer platinum................	708	373	641	266	100	566
Japan:						
Palladium from refineries........	—	32	59	23	85	—
Platinum from refineries.........	299	68	151	245	484	997
New Guinea.....................	—	4	—	5	2	6
New Zealand:						
Placer platinum................	3	—	—	8	4	—
Papua: Placer platinum...........	—	—	—	2	5	—
Sierra Leone:						
Placer platinum................	132	38	—	—	—	—
Union of South Africa:						
P.atinum group metals from platinum ores................	22,630	30,470				
Concentrates, platinum group metal content from platinum ores........................	52,511	56,904	144,217	190,898	232,521	299,177
Osmiridium from gold ores......	6,018	6,031	6,449	6,359	6,141	6,966
U.S.S.R.: Placer platinum and from refining nickel-copper ores (estimate)....................	150 000	100,000	100,000	100,000	100,000	100,000
United States: Placer platinum and from domestic gold and copper refining......................	27,113	24,807	37,855	36,951	34,409	26,072
Total (estimate)..............	620,000	575,000	600,000	675,000	675,000	750,000

ACKNOWLEDGMENT: Bureau of Mines *Minerals Yearbook*, "Platinum-Group Metals", by James E. Bell and Kathleen M. McBreen, 1953.

Table XXIV

CANADIAN SILVER PRODUCTION BY ORE SOURCES, 1936-55

(thousands of troy ounces)

Year	Gold ores	Copper-gold -silver ores	Nickel-copper ores	Silver-lead -zinc ores	Silver-cobalt and other ores	Total
1936	1,773	2,026	2,484	9,807	2,244	18,334
1937	1,786	2,644	2,364	14,369	1,815	22,978
1938	1,849	3,583	2,505	13,009	1,273	22,219
1939	2,040	3,680	2,497	13,449	1,498	23,164
1940	2,399	4,356	2,803	12,986	1,290	23,834
1941	2,726	4,866	2,462	11,127	573	21,754
1942	2,150	5,177	2,238	10,275	855	20,695
1943	1,403	5,201	1,649	8,949	143	17,345
1944	863	3,795	1,829	6,443	697	13,627
1945	1,218	3,269	1,735	6,245	476	12,943
1946	1,029	2,926	1,206	6,954	429	12,544
1947	761	2,867	1,435	7,110	331	12,504
1948	1,017	3,374	1,404	9,336	979	16,110
1949	700	3,968	1,202	10,810	961	17,641
1950	733	4,335	1,045	14,163	2,945	23,221
1951	733	4,254	1,128	14,051	2,960	23,126
1952	707	3,432	1,231	15,007	4,845	25,222
1953	635	3,353	1,255	19,519	3,537	28,299
1954	678	3,947	1,292	21,469	3,732	31,118
1955	668	4,109	1,497	17,642	4,068	27,984

SOURCE: D.B.S., *Mineral Statistics*, "Section C", Silver, Lead and Zinc Mining Industry.

Table XXV

ASBESTOS PRODUCTION, EXPORTS AND CONSUMPTION, 1926-55

Year	Canada: Production	Canada: Exports	Canada: Apparent consumption	Canada: Production as % of world consumption	World consumption exclud. U.S.S.R.	North American apparent consumption
	(in thousands of short tons)					
1926....	279	278	1	—	—	—
1927....	275	263	12	—	—	—
1928....	273	265	8	73.3	372	—
1929....	306	292	14	75.0	408	—
1930....	242	236	6	77.1	314	—
1931....	164	159	5	76.6	214	145
1932....	123	112	11	77.4	159	110
1933....	158	149	9	70.8	223	132
1934....	156	158	— 2	68.3	228	122
1935....	211	200	11	69.2	305	186
1936....	301	294	7	72.9	421	258
1937....	410	391	19	76.0	538	335
1938....	290	289	1	75.1	399	188
1939....	365	346	19	74.6	489	275
1940....	347	337	10	70.3	494	272
1941....	478	454	24	76.5	625	463
1942....	440	428	12	73.8	596	446
1943....	467	443	24	78.4	596	470
1944....	419	396	23	75.6	553	430
1945....	467	441	26	83.8	557	404
1946....	558	520	38	78.8	708	498
1947....	662	637	25	78.1	835	642
1948....	717	690	27	75.8	946	705
1949....	575	535	40	66.6	864	575
1950....	875	830	45	73.5	1,190	774
1951....	973	942	31	73.3	1,328	828
1952....	929	902	27	70.0	1,328	780
1953....	911	879	32	71.6	1,273	776
1954....	924	888	36	65.2	1,417[a]	776[a]
1955....	1,055	1,002	53	66.2	1,593[a]	780[a]

a Estimated.

SOURCE: *Statistics Relating to the Canadian Mineral Industry*, prepared for the Commission by Mineral Resources Division, Dept. of Mines and Technical Surveys.

Appendix F

OTHER STUDIES TO BE PUBLISHED BY THE ROYAL COMMISSION

Output, Labour and Capital in the Canadian Economy—
by Wm. C. Hood and Anthony Scott

Canadian Energy Prospects—
by John Davis

Progress and Prospects of Canadian Agriculture—
by W. M. Drummond and W. Mackenzie

The Commercial Fisheries of Canada—
by The Fisheries Research Board and The Economic Service of The Department of Fisheries of Canada

The Outlook for the Canadian Forest Industries—
by John Davis, A. L. Best, P. E. Lachance, S. L. Pringle, J. M. Smith, D. A. Wilson

Canadian Secondary Manufacturing Industry—
by D. H. Fullerton and H. A. Hampson

The Canadian Primary Iron and Steel Industry—
by The Bank of Nova Scotia

The Canadian Automotive Industry—
by The Sun Life Assurance Company of Canada

The Canadian Agricultural Machinery Industry—
by J. D. Woods & Gordon Limited

The Canadian Industrial Machinery Industry—
by Urwick, Currie Limited

The Canadian Electrical Manufacturing Industry—
by Clarence L. Barber

The Electronics Industry in Canada—
by Canadian Business Service Limited

The Canadian Primary Textiles Industry—
by National Industrial Conference Board (Canadian Office)

The Canadian Construction Industry—
by The Royal Bank of Canada

The Canadian Chemical Industry—
by John Davis

The Service Industries—
by The Bank of Montreal

Probable Effects of Increasing Mechanization in Industry—
by The Canadian Congress of Labour, now
The Canadian Labour Congress

Labour Mobility—
by The Trades and Labor Congress of Canada, now
The Canadian Labour Congress

Skilled and Professional Manpower in Canada, 1945-1965—
by The Economics and Research Branch, Department
of Labour of Canada

Transportation in Canada—
by J-C. Lessard

Industrial Concentration—
by The Canadian Bank of Commerce

Housing and Social Capital—
by Yves Dubé, J. E. Howes and D. L. McQueen

Financing of Economic Activity in Canada—
by Wm. C. Hood, including A Presentation of National Transactions Accounts in Canada, 1946-54, by L. M. Read, S. J. Handfield-Jones and F. W. Emmerson

Certain Aspects of Taxation Relating to Investment in Canada by Non-Residents—
by J. Grant Glassco of Clarkson, Gordon & Co.,
Chartered Accountants

Consumption Expenditures in Canada—
by David W. Slater

Canada's Imports—
by David W. Slater

[1]This is one of a series of three studies on Canadian international economic relations prepared under the direction of S. S. Reisman.

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QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
1957

INDEX TO PRINCIPAL PRODUCTIVE MINES

DECEMBER 1956

(WITH NAMES OF OPERATING COMPANIES)

NEWFOUNDLAND

1. Iron Ore Co. of Canada Iron ore
1. Buchans Mining Co. Ltd. Zinc, Lead, Copper, Silver, Gold, Pyrite
1. Dominion Wabana Ore Ltd. Iron ore

1. Atlantic Gypsum Ltd. Gypsum
2. Newfoundland Fluorspar Ltd. Fluorspar
3. St. Lawrence Corp. of Newfoundland Ltd. Fluorspar

NOVA SCOTIA

1. Sifto Salt Ltd. Salt
2. Canadian Gypsum Co. Ltd. Gypsum
3. Gypsum Lime and Alabastine Canada Ltd. Gypsum
4. Magnet Cove Barium Corp. Barite
5. National Gypsum (Canada) Ltd. Gypsum
6. National Gypsum (Canada) Ltd. Gypsum
7. Malagash Salt Co. Ltd. Salt
8. Little Narrows Gypsum Co. Ltd. Gypsum

1. Cumberland Railway and Coal Co. Coal
1. Indian Cove Coal Co. Coal
1. Joggins Coal Co. Ltd. Coal
2. Acadia Coal Co. Ltd. Coal
3. Drummond Coal Ltd. Coal
3. Bras D'Or Coal Co. Ltd. Coal
4. Old Sydney Collieries Ltd. Coal
4. Dominion Coal Co. Ltd. Coal

NEW BRUNSWICK

1. Canadian Gypsum Co. Ltd. Gypsum

1. Avon Coal Co. Ltd. Coal
1. A.W. Wasson Ltd. Coal
1. D.W. and R.A. Mills Ltd. Coal
1. King Mining Co. Ltd. Coal
1. Atlantic Lumber Co. Ltd. Coal
1. Newcastle Coal Co. Ltd. Coal

QUEBEC

1. Normetal Mining Corp. Ltd. Zinc, Copper, Silver, Gold, Pyrite
1. Beattie-Duquesne Mines Ltd. Copper
1. Elder Mines Ltd. Gold
1. Eldrich Mines Ltd. Gold
1. Lyndhurst Mining Co. Ltd. Copper
1. Noranda Mines Ltd. Copper, Gold, Silver, Selenium, Tellurium, Pyrite
1. Quemont Mining Corp. Ltd. Copper, Gold, Zinc, Silver, Pyrite
2. Stadacona Mines (1944) Ltd. Gold
2. Waite Amulet Mines Ltd. Copper, Zinc, Gold, Silver, Pyrite
2. West MacDonald Mines Ltd. Copper, Zinc, Pyrite
3. Barnat Mines Ltd. Gold
3. Canadian Malartic Gold Mines Ltd. Gold
3. East Malartic Mines Ltd. Gold
3. Malartic Gold Fields Ltd. Gold
3. Molybdenite Corp. of Canada Ltd. Molybdenum, Bismuth
4. Beacon Gold Mines Ltd. Gold
4. East Sullivan Mines Ltd. Copper, Zinc, Gold, Silver, Pyrite
4. Manitou-Barvue Mines Ltd. Zinc, Silver, Lead, Gold, Copper
4. Lamaque Gold Mines Ltd. Gold
4. [illegible] Mines Ltd. Copper, Gold, Silver
4. Sigma Mines (Quebec) Ltd. Gold
5. Barvue Mines Ltd. Zinc, Silver
6. Belleterre Quebec Mines Ltd. Gold
7. New Calumet Mines Ltd. Zinc, Lead, Gold, Silver
8. Quebec Copper Corp. Ltd. Copper
9. Weedon Pyrite and Copper Corp. Ltd. Copper, Zinc, Pyrite
10. Campbell Chibougamau Mines Ltd. Copper, Gold
11. Opemiska Copper Mines (Quebec) Ltd. Copper, Gold
12. Chibougamau Explorers Ltd. Copper, Gold
13. Gaspe Copper Mines Ltd. Copper, Gold, Silver, Selenium, Tellurium
14. Quebec Iron and Titanium Corp. Iron, Titanium Dioxide slag
15. Iron Ore Co. of Canada Iron ore

1. Quebec Lithium Corp. Lithia
2. Aluminum Co. of Canada Ltd. Brucitic Limestone
3. Blackburn Bros. Mica
4. International Minerals and Chemical Corp. (Canada) Ltd. Feldspar
5. Dominion Silica Corp. Ltd. Silica
6. Canadian Refractories Ltd. Magnesitic Dolomite
7. Canadian Silica Corp. Ltd. Silica
8. Electro Metallurgical Co., Division of Union Carbide Canada Ltd. Silica
9. Baker Talc Ltd. Talc
10. Sherwin-Williams Co. of Canada Ltd. Iron Oxide (mineral pigment)
11. Canadian Johns-Manville Co. Ltd. Asbestos
11. Nicolet Asbestos Mines Ltd. Asbestos
12. Asbestos Corp. Ltd. Asbestos
12. Bell Asbestos Mines Ltd. Asbestos
12. Flintkote Mines Ltd. Asbestos
12. Johnson's Asbestos Co. Asbestos
12. Johnson's Co. Ltd. Asbestos
13. Broughton Soapstone and Quarry Co. Ltd. Soapstone, Talc
13. Quebec Asbestos Corp. Ltd. Asbestos

ONTARIO

1. Campbell Red Lake Mines Ltd. Gold
1. Cochenour Willans Gold Mines Ltd. Gold
1. Madsen Red Lake Gold Mines Ltd. Gold
1. McKenzie Red Lake Gold Mines Ltd. Gold
1. New Dickenson Mines Ltd. Gold
2. Steep Rock Iron Mines Ltd. Iron ore
3. Pickle Crow Gold Mines Ltd. Gold
4. Leitch Gold Mines Ltd. Gold
5. MacLeod-Cockshutt Gold Mines Ltd. Gold
6. Algoma Ore Properties Ltd. Iron ore
7. Renabie Mines Ltd. Gold
8. Jardun Mines Ltd. Zinc, Lead, Silver
9. Algom Uranium Mines Ltd. Uranium
10. Pronto Uranium Mines Ltd. Uranium
11. Aunor Gold Mines Ltd. Gold
11. Broulan Reef Mines Ltd. Gold
11. Coniaurum Mines Ltd. Gold
11. Delnite Mines Ltd. Gold
11. Dome Mines Ltd. Gold
11. Hallnor Mines Ltd. Gold
11. Hollinger Consolidated Gold Mines Ltd. (Hollinger) Gold
11. Hugh-Pam Porcupine Mines Ltd. Gold
11. McIntyre Porcupine Mines Ltd. Gold
11. Pamour Porcupine Mines Ltd. Gold
11. Paymaster Consolidated Mines Ltd. Gold
11. Preston East Dome Mines Ltd. Gold
12. Hollinger Consolidated Gold Mines Ltd. (Ross) Gold
13. Kerr Addison Gold Mines Ltd. Gold
13. Kirkland Minerals Corp. Ltd. Gold
13. Lake Shore Mines Ltd. Gold
13. Macassa Mines Ltd. Gold
13. Sylvanite Gold Mines Ltd. Gold
13. Teck-Hughes Gold Mines Ltd., The Gold
13. Upper Canada Mines Ltd. Gold
13. Wright-Hargreaves Mines Ltd. Gold
14. Min-Ore Mines Ltd. Copper, Gold
15. Castle-Trethewey Mines Ltd. Silver, Cobalt
15. Siscoe Metals of Ontario Ltd. Silver, Cobalt
16. Cobalt Consolidated Mining Corp. Ltd. Silver, Cobalt
16. Nipissing-O'Brien Mines Ltd. Silver, Cobalt
16. Silver Crater Mines Ltd. Cobalt, Silver
16. Silver-Miller Mines Ltd. Silver, Cobalt, Copper
17. Temagami Mining Co. Ltd. Copper
18. Falconbridge Nickel Mines Ltd. Nickel, Copper, Gold, Silver, Platinum metals, Cobalt
18. Nickel Rim Mines Ltd. Nickel, Copper
19. International Nickel Co. of Canada Ltd., The Copper, Nickel, Gold, Silver, Platinum metals, Cobalt, Selenium, Tellurium, Iron ore
19. Nickel Offsets Ltd. Nickel, Copper
20. Dominion Magnesium Ltd. Magnesium, Calcium
21. Bicroft Uranium Mines Ltd. Uranium
22. Marmoraton Mining Co. Ltd. Iron Ore

1. Canadian Johns-Manville Co. Ltd. Asbestos
2. Electro Metallurgical Co., Division of Union Carbide Canada Ltd. Silica
3. Canadian Silica Corp. Ltd. Silica
4. Sifto Salt Ltd. Salt
5. Warwick Pure Salt Co. Ltd. Salt
6. Sifto Salt Ltd. Salt
7. Canadian Rock Salt Co. Ltd. The, Salt
7. Canadian Salt Co. Ltd., The Salt
8. Canadian Gypsum Co. Ltd. Gypsum
9. Gypsum, Lime and Alabastine, Canada Ltd. Gypsum
10. American Nepheline Ltd. Nepheline Syenite
10. International Minerals and Chemical Corp. (Canada) Ltd. Nepheline Syenite
11. Building Products Ltd. Roofing Granules
12. Canada Talc Industries Ltd. Talc
12. Huntingdon Fluorspar Mines Ltd. Fluorspar

MANITOBA

1. Sherritt Gordon Mines Ltd. Nickel, Copper, Cobalt
2. Hudson Bay Mining and Smelting Co. Ltd. Copper, Zinc, Gold, Silver, Cadmium, Selenium, Tellurium
3. Britannia Mining and Smelting Co. Ltd. (Nor-Acme Mine) Gold
4. Forty-Four Mines Ltd. Gold
4. San Antonio Gold Mines Ltd. Gold

1. Gypsum, Lime, and Alabastine, Canada Ltd. Gypsum
2. Western Gypsum Products Ltd. Gypsum
3. Canadian Salt Co. Ltd., The Salt
4. Pembina Mountain Clays Ltd. Bentonite

SASKATCHEWAN

1. Black Bay Uranium Ltd. Uranium
1. Consolidated Nicholson Mines Ltd. Uranium
1. Eldorado Mining and Refining Ltd. (Fay and Ace Mines) Uranium
1. Gunnar Mines Ltd. Uranium
1. National Explorers Ltd. Uranium
1. Radiore Uranium Mines Ltd. Uranium
1. Rix-Athabasca Uranium Mines Ltd. Uranium
2. Hudson Bay Mining and Smelting Co. Ltd. Copper, Zinc, Gold, Silver, Cadmium, Selenium, Tellurium

1. Sifto Salt Ltd. Salt
2. Midwest Chemicals Ltd. Sodium Sulphate
3,4,5. Saskatchewan Minerals (Sodium Sulphate Division) Sodium Sulphate
6. Ormiston Mining & Smelting Co. Ltd. Sodium Sulphate
7. Sybouts Sodium Sulphate Co. Ltd. Sodium Sulphate

1. Manitoba and Saskatchewan Coal Co. Ltd. Coal
1. Portal Coals Ltd. Coal
1. Western Dominion Coal Mines Ltd. Coal

ALBERTA

1. Canadian Salt Co. Ltd., The Salt

1. Luscar Coals Ltd. Coal
2. Canadian Collieries (Dunsmuir) Ltd. Coal
3. Alberta Coal Co. Ltd. Coal
4. Battle River Coal Ltd. Coal
4. Forestburg Collieries Ltd. Coal
5. Amalgamated Coals Ltd. Coal
5. Century Coals Ltd. Coal
5. Midland Coal Mining Co. Ltd. Coal
5. Murray Collieries Ltd. Coal
5. Red Deer Valley Coal Co. Ltd. Coal
6. Canmore Mines Ltd., The, Coal
7. Coleman Collieries Ltd. Coal
8. West Canadian Collieries Ltd. Coal
9. Lethbridge Collieries Ltd. Coal

BRITISH COLUMBIA

1. Tulsequah Mines Ltd. Copper, Lead, Zinc, Gold, Silver, Cadmium
2. Torbrit Silver Mines Ltd. Silver, Lead
3. Silver Standard Mines Ltd. Silver, Lead, Zinc, Cadmium
4. Cariboo Gold Quartz Mining Co. Ltd., The Gold
5. Bralorne Mines Ltd. Gold
5. Pioneer Gold Mines of B.C. Ltd. Gold
6. Utah Co. of the Americas (Argonaut Mine Division) Iron ore
7. Texada Mines Ltd. Iron ore
8. Britannia Mining and Smelting Co. Ltd. Copper, Gold, Silver, Zinc, Pyrite, Cadmium
9. Granby Consolidated Mining, Smelting & Power Co. Ltd., The Copper, Gold, Silver
10. Highland-Bell Ltd. Silver, Lead, Zinc
11. Sunshine Lardeau Mines Ltd. Lead, Zinc, Silver
12. Giant Mascot Mines Ltd. Lead, Zinc, Silver
13. Sheep Creek Mines Ltd. Zinc, Lead, Silver
14. Violamac Mines Ltd. Lead, Silver, Zinc
14. Yale Lead and Zinc Mines Ltd. Lead, Zinc, Silver, Cadmium
15. Consolidated Mining and Smelting Co. of Canada Ltd., The (Bluebell) Lead, Zinc, Cadmium
16. Consolidated Mining and Smelting Co. of Canada Ltd., The (Sullivan) Lead, Zinc, Gold, Silver, Antimony, Cadmium, Bismuth, Tin, Indium, Pyrrhotite
17. Canadian Exploration Ltd. Zinc, Lead, Tungsten, Cadmium
17. Consolidated Mining and Smelting Co. of Canada Ltd., The (H.B. Mine) Zinc, Lead
17. Reeves MacDonald Mines Ltd. Zinc, Lead, Cadmium, Silver

1. Cassiar Asbestos Corp. Ltd. Asbestos
2. Gypsum, Lime and Alabastine, Canada, Ltd. Gypsum
3. Mountain Minerals Ltd. Barite
4. Columbia Gypsum Co. Ltd. Gypsum

1. Canadian Collieries (Dunsmuir) Ltd. Coal
2. Crow's Nest Pass Coal Co. Ltd. Coal
3. Coleman Collieries Ltd. Coal

YUKON TERRITORY

1. Yukon Explorations Ltd. Gold (placer)
2. Yukon Consolidated Gold Corp. Ltd., The Gold
3. Galkeno Mines Ltd. Silver, Lead, Zinc
3. United Keno Hill Mines Ltd. Silver, Lead, Zinc, Cadmium

NORTHWEST TERRITORIES

1. Eldorado Mining and Refining Ltd. Uranium, Radium, Silver
2. Consolidated Discovery Yellowknife Mines Ltd., Gold
3. Consolidated Mining and Smelting Co. of Canada Ltd., The (Con Mine) Gold
3. Giant Yellowknife Gold Mines Ltd. Gold

NOTES

1. Most of the lode gold mines as shown also produce some silver
2. Clay Products and Structural Materials not shown

VALUE OF MINERAL PRODUCTION OF CANADA BY PROVINCES, 1956 (Preliminary Estimates)

Province or Territory	Metals	Fuels	Industrial Minerals	Total for Province or Territory	Per Cent of Total
Newfoundland	79,858,435	—	7,893,590	87,752,025	4.6
Nova Scotia	1,005,321	51,029,641	14,590,264	66,625,226	3.2
New Brunswick	158,608	5,090,980	9,922,166	18,171,454	0.9
Quebec	236,018,292	—	189,295,453	425,306,245	21.8
Ontario	512,255,983	7,137,500	121,422,066	640,915,058	31.1
Manitoba	39,009,137	13,023,330	13,840,410	66,711,347	3.2
Saskatchewan	70,375,771	16,187,661	7,144,884	114,100,316	5.9
Alberta	9,111	388,707,027	20,943,004	409,801,420	21.1
British Columbia	157,717,291	8,851,043	38,713,136	199,318,574	8.6
N.W. Territories	31,801,779	1,347,558	—	33,949,122	1.1
Yukon Territory	15,505,647	131,860	—	15,676,852	0.8
CANADA	1,114,354,350	514,830,071	418,684,855	2,047,669,096	100.0

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INDEX TO PRINCIPAL OIL AND GAS FIELDS

DECEMBER 1956

NEW BRUNSWICK

1. Stoney Creek Oil, Gas

ONTARIO

1. Oil Springs Oil
2. Petrolia Oil

MANITOBA

1. North Virden Oil
2. Virden-Roselea Oil
3. Daly Oil

SASKATCHEWAN

1. Lloydminster Oil, Gas

ALBERTA

1. Peace Coupe Gas

BRITISH COLUMBIA

1. Boundary Lake Oil
2. Fort St. John Gas

NORTHWEST TERRITORIES

1. Norman Wells Oil